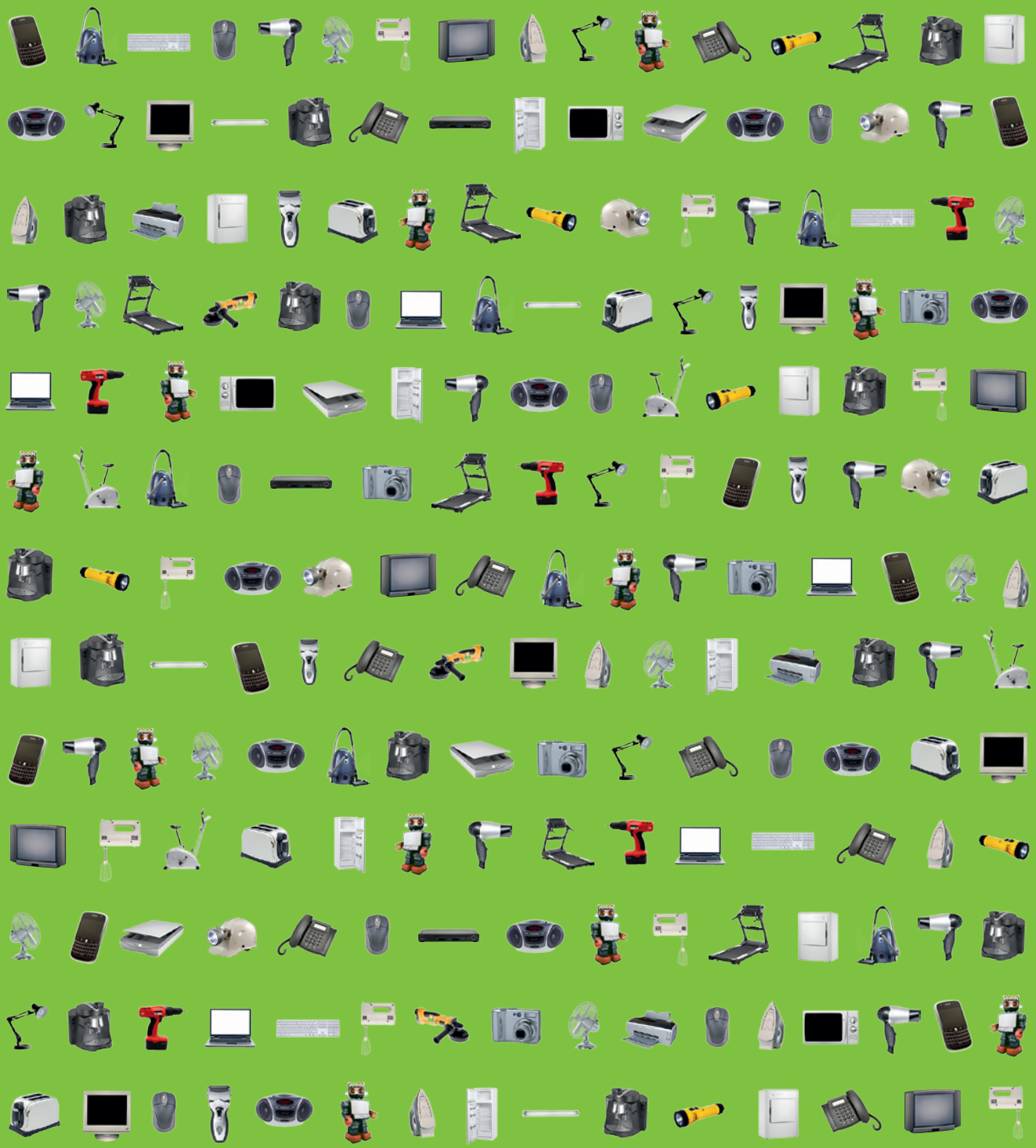
2011

Report of the Technical Inspectorate
SENS, SWICO Recycling, SLRS



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A further milestone in our partnership

SWICO Recycling, SENS and SLRS (Swiss Lighting Recycling Foundation), the three Swiss recycling systems in the field of electrical and electronic equipment, as well as illuminants and lighting equipment are systematically expanding their tried and tested collaboration even further. For some years already, SWICO Recycling and SENS have carried out the technical inspections of recycling operations together. In 2008, cooperation was intensified with the creation of a joint technical commission. This step heralded an extension of the existing collaboration between SENS and SLRS. Then, as a contractual partner of SLRS, SENS has transformed collection, transport, recycling, inspections and reporting with its take-back and recycling system. A further milestone in the collaboration between SWICO Recycling, SENS and SLRS followed in June 2009, when the technical processing regulations were combined and harmonised. The Federal Office for the Environment regards these technical processing regulations as the state-of-the-art for processing technology in respect of electrical and electronic equipment as well as illuminants and lighting equipment.

Now the next step in consolidating cooperation between the three organisations is taking place. With this report, which is aimed at a technically minded readership, a joint technical report by SWICO Recycling, SENS and SLRS is being published for the first time. The technical report covers fields where all three organisations operate, but also highlights aspects which only involve one particular take-back system. It provides an overview of the key events of the past year as well as considering current themes.

We have great pleasure in submitting the 2011 Technical Report to you. We hope that this joint publication of SWICO Recycling, SENS and SLRS will generate keen interest and look forward to receiving feedback.

Environmentally friendly recycling assured

Besides collecting used electrical and electronic equipment, its correct processing is another important function of SENS and SWICO Recycling. The two independent technical inspection bodies belonging to SWICO Recycling and SENS share a joint Technical Inspectorate where they coordinate the technical requirements and their implementation in the course of inspections.

The most important aims of the SENS Foundation and SWICO Recycling are removing components containing harmful substances, and recycling as much as possible, if not all, of these materials from end-of-life electrical and electronic equipment. Only those materials that cannot be recycled are converted to energy via thermal recycling. Inspections enable the joint Technical Inspectorate of SENS and SWICO Recycling to make sure that recycling and disposal are carried out correctly and in accordance with uniform principles. Similarly, independent inspectors conduct the cantonal inspections in the cantons of Zurich, Aargau and Thurgau within the scope of SENS and SWICO Recycling delegated inspections (cf. Amount page 22).

Focus on removal

To ensure the electrical and electronic equipment are always recycled and disposed of correctly and efficiently, the joint Technical Inspectorate stipulates the technical requirements for their recycling and disposal, and the inspection and reporting systems they entail. Annual inspections make certain that the recycling and disposal services are performed correctly. The inspectors pay particular attention to checking the evidence for the flow of materials and goods, the removal of harmful substances and environmentally compatible recycling and disposal of the end products. The protocols make sure that compliance with the technical requirements is systematically documented. Any necessary corrective measures are defined as pending tasks and deadlines set for their completion. The recycling company concerned must not only record these but also carry out a further inspection on site in individual cases.

Expertise in demand abroad

The members of the Technical Inspectorate receive regular further training. Their knowledge and expertise are in demand abroad. This is why the members also hold various mandates in working groups of the European Association of Electrical and Electronic Waste Take Back Systems (WEEE Forum: see report page 20). The Inspectorate regularly coordinates its work with the remaining activities of SENS and SWICO Recycling so that it can structure the entire range of services for the environmentally friendly recycling and disposal of electrical and electronic equipment efficiently and cost-effectively.

Close cooperation with the cantons

Since 2006, the cantons (ZH, AG und TG) have delegated the legally defined inspection tasks to the Technical Inspectorate of SENS and SWICO Recycling as much as possible. This means the inspectors perform all of the tasks involved while previously agreed dates for the annual inspections enable the relevant cantonal representatives to get a clear idea of what is happening locally. The reports issued on behalf of the cantons not only document the status quo, but also enable the quality and quantity of inspections to be compared across the board. This ensures that Switzerland continues to remain a world leader in recycling and disposal.

SENS, SWICO Recycling, SLRS: sustainable and efficient

The three recycling systems SENS, SWICO Recycling and SLRS have been assuring the take-back, recycling and correct disposal of electrical and electronic equipment for around 20 years. The increasing quantities of returned goods demonstrate how successful the work of the three systems is.

Responsibility for recycling electrical and electronic equipment is shared by three organisations in Switzerland. The reasons for sharing this responsibility are historical: in the early years of institutionalised recycling, the systems were industry specific. The aim was to ensure that each of the systems was closely associated with a particular industry in order to be able to respond to its specific needs. Shared responsibility also served as a means of addressing any initial reservations about participating in the existing take-back system, which was, and still is, voluntary. Today, depending on the type of appliance involved, either SWICO Recycling, the SENS Foundation or SLRS (Stiftung Licht Recycling Schweiz/Swiss Lighting Recycling Foundation) is responsible for taking back and recycling that appliance.

In 2011, a total of 118,610[1)] tonnes of end-of-life electrical and electronic equipment were recycled by the three systems. This has enabled SWICO Recycling, SENS and SLRS to make a significant contribution to re-introducing valuable raw materials into the business cycle. Moreover, membership of international networks at European level, for example the WEEE Forum (Forum for Waste Electrical and Electronic Equipment), has enabled the three organisations to help determine cross-border benchmarks for recycling electrical and electronic equipment.

The Ordinance on the Return and Recycling of Electrical and Electronic Appliances (ORAREEA) requires dealers, manufacturers and importers to take back the appliances included in their product ranges free of charge. An advance recycling fee (ARF) is levied on these appliances at the point of sale in order to finance the sustainable, environmentally friendly and, at the same time, competitive recycling of electrical and electronic equipment. The ARF is an efficient financial instrument which ensures that SWICO Recycling, SENS and SLRS are responsible not only for processing the appliances in their respective sectors correctly, but also for facing future challenges.

SWICO Recycling

SWICO Recycling is a neutral, non-profit commission of the Swiss Association for Information, Communication and Organisation Technology. The aims of its work are to recover raw materials and dispose of harmful substances in an environmentally friendly way. SWICO Recycling deals primarily with IT, entertainment, office and telecommunications equipment, as well as equipment from the graphics industry and measuring and medical technology, such as copiers, printers, TVs, MP3 and MP4 players, mobile phones, cameras, etc. Its close partnership with Empa, a Swiss research and service institution for applied materials sciences and technology development within the Swiss Federal Institute of Technology (ETH), is one of the main reasons why SWICO Recycling is able to ensure high, uniform quality standards in all the recycling and waste disposal systems throughout Switzerland.

[1)] This is a matter of the quantity as per the material flow reports of recycling operations. This is not the same as the calculated quantity as per the respective annual business reports of SENS and Swico Recycling.

SENS Foundation

SENS is an independent, neutral non-profit foundation. It concentrates on the return, recycling and disposal of large and small electrical and electronic domestic equipment, building, garden and hobby equipment, as well as toys and games. In addition, SENS works closely with specialised networks in which the parties involved in recycling electrical and electronic equipment are represented. Together with its partners, SENS seeks to ensure that these appliances are recycled in accordance with economic and eco-friendly principles.

During the course of 2011, SENS achieved about a 6 % increase in the volume of recycled refrigeration, deep-freeze and air-conditioning appliances, a further rise on top of last year's increase. Clearly, there is no sign that the volume of recycled refrigeration appliances has reached the saturation point forecast in 2009. In 2011, the total volume recycled in the SENS system increased by a further 3 %.

Swiss Lighting Recycling Foundation (SLRS)

The Swiss Lighting Recycling Foundation (SLRS) is primarily responsible for the system for illuminants and lighting equipment. It is in charge of organising the large-scale disposal of lighting equipment throughout Switzerland. To finance this work, SLRS manages a fund for illuminants and lighting equipment, paid for by the respective ARF. Furthermore, the work of SLRS includes providing training and awareness-raising sessions related to recycling illuminants and lighting equipment for the market participants, as well as information for all the stakeholder groups. In 2011 SLRS processed 1,114 tonnes of end-of-life illuminants. It maintains close ties with its partner SENS in all related areas. Accordingly, as a contractual partner of SLRS, SENS incorporates not only collection and transportation, but also recycling, inspection and reporting on illuminants and lighting equipment within its own take-back and recycling system.

Increasing quantity of raw materials extracted

Despite a nationwide decline in the collection and processing of large domestic appliances in Switzerland, SENS and SWICO Recycling were able to maintain the quantity of recycled EE equipment at a stable level. In total, around 75 % of the material extracted from EE equipment was recycled.

Year on year, the recyclers submitted their materials flow data to a detailed materials flow database which is monitored and looked after by Empa. Thanks to this database, details of the development of the recycling of electrical and electronic equipment in Switzerland can be shown over time. The quantity of EE equipment processed by SENS and SWICO recyclers in 2011 has hardly increased at all compared with the previous year → Table 1 and → Fig. 2. This stagnation is mainly caused by the 10 % decline in the amount of domestic appliances collected and processed. The volume of small electrical appliances along with refrigeration, deep-freeze and air-conditioning appliances has increased slightly, each by 6 %, as it did in the previous year. After strong growth in 2010, the quantity of electronic appliances processed (information and communications technologies and entertainment electronics) has scarcely increased since, while the quantity of lighting equipment remains stable.

The biggest increase in processing involved appliances which are not listed in ORAREEA (the Ordinance on the Return and Recycling of Electrical and Electronic Appliances). Thus it is a matter of appliances which are used in trade and industry or in hospitals. The strong rise is due to an increase in the number of contracts from industry, which are settled directly between the SENS and SWICO recyclers and their industrial partners.

Raw material extraction and pollutant removal

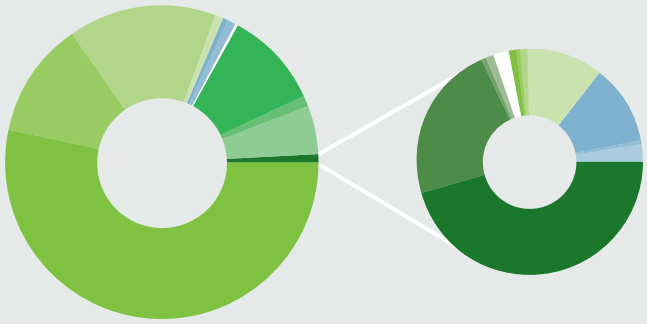
During the recycling process, appliances are separated manually and mechanically into the various recyclable material and pollutant fractions. Here the manual activities play an important part despite extensive automation. Thus particularly valuable appliance parts and components as well as those containing pollutants continue to be sorted by hand. → Fig. 1 shows the exact composition of a total of 118,610 tonnes of processed appliances. These consist mainly of metals (53 %) and to a

Table 1: Total volume of waste electrical and electronic equipment processed in Switzerland in tonnes, taken from the materials flow records

Year	Large electrical appliances	Refrigeration, deep-freeze & air-conditioning appliances	Small electrical appliances	Electronic appliances	Lighting equipment	Non-ORAREEA appliances	Total tonnes/year
2000	9,600	6,900	total 19,800				36,300
2001	9,600	6,700	total 17,500				33,800
2002	5,600	6,400	total 22,300			300	34,600
2003	14,600	11,600	5,400	30,200		800	62,600
2004	18,100	13,100	7,500	33,700		1,800	74,200
2005	19,100	11,400	9,300	37,200	420[1)]	1,900	79,320
2006	23,400	15,300[2)]	10,700	41,800	1,100	4,200	96,500[2)]
2007	26,100	14,500	12,300	42,500	1,110	2,900	99,410
2008	26,800	15,100	13,800	45,000	1,130	2,300	104,130
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	117,330
2011	27,800	16,800	16,300	51,400	1,110	5,200	118,610
Changes compared with previous year	**–9 %**	**6 %**	**6 %**	**1 %**	**–2 %**	**49 %**	**1 %**

[1)] Figures were only collected for five months in 2005 since the introduction of the advance recycling fee (ARF) on 1 August 2005.
[2)] In 2006, 1,300 tonnes of commercial equipment were included in the statistical data for refrigeration appliances in addition to household appliances.

Fig. 1: Composition of fractions produced in % in 2011
Pollutants, shown separately, account for 1 % of the total fractions produced.



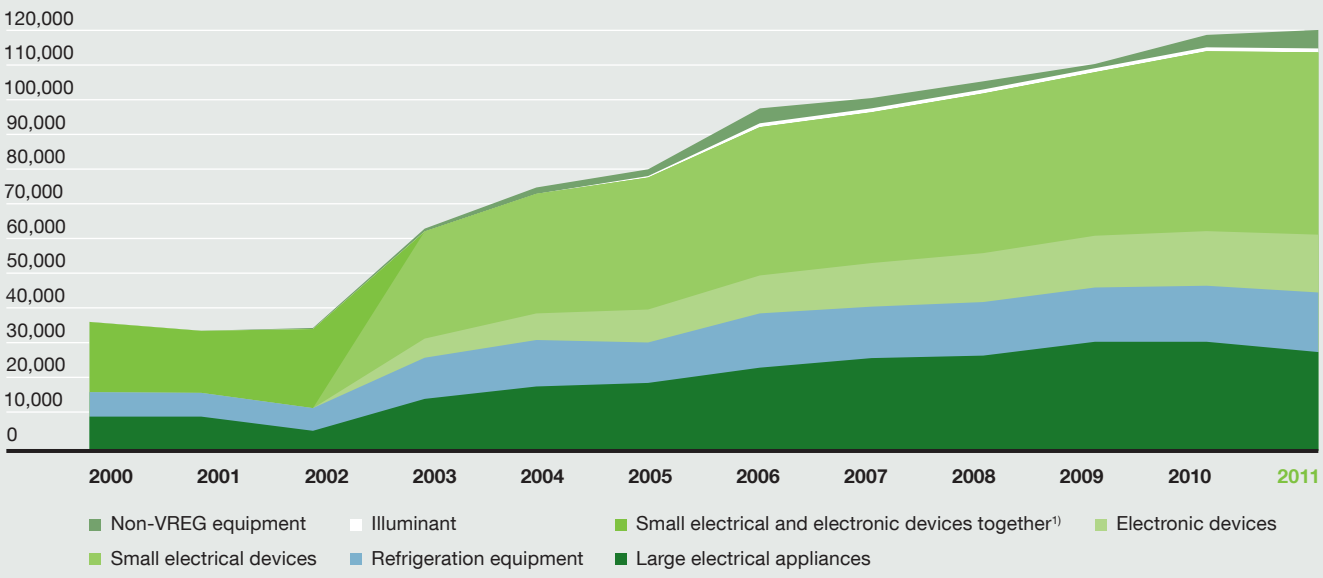
53 %	Metals
12 %	Plastic/metal composites
15 %	Plastics
1 %	Cable
0.4 %	Toner cartridges
1 %	Printed circuit boards
0.2 %	LCDs
10 %	CR tubes
1 %	Glass
5 %	Other materials
1 %	Pollutants

0.4 %	Batteries
0.2 %	Capacitors
0.002 %	Mercury
0.01 %	Broken glass
0.02 %	Phosphorus
0.01 %	Getter pills
0.0001 %	Selenium
0.01 %	Asbestos
0.1 %	CFCs
0.1 %	Oil, all
0.005 %	Ammonia (NH_3)
0.02 %	Other pollutants

lesser extent plastics (15 %), metal/plastic composites (12 %) and cathode ray tubes from old monitors and TV sets (10 %). Printed circuit boards (which contain particularly valuable materials) as well as pollutants account for only 1 % of the total volume processed. The volumes of individual recyclable fractions have only changed slightly compared with 2010.

The supposed small quantities of pollutants (around 1,800 tonnes) in EE equipment should not be taken to mean that pollutant removal is not one of the highest priorities of a SENS-SWICO recycler alongside the extraction of raw materials. The total amount of pollutants removed has remained constant relative to the previous year. The quantity of batteries and capacitors has increased by 22 % and 15 % respectively which points, on the one hand, to an increase in off-grid battery-operated appliances and, on the other, however, also to an improvement in pollutant removal techniques. Likewise, the quantity of waste asbestos has increased steadily in recent years, which underlines the steady improvement in the sorting by recyclers of equipment containing asbestos. There has been a marked decrease in the quantities of mercury, getter pills and selenium drums. Similarly, CFCs and oils show a slight decrease.

Fig. 2: Development of volume of appliances processed in Switzerland in tonnes



1) Until 2002, small electrical and electronic devices were classed together

Cooperation abroad

With few exceptions, the primary processing of appliances takes place in Switzerland. The quantity processed abroad amounts to 1,700 tonnes. It accounts for less than 1 % of the total quantity and involves large domestic appliances, refrigeration appliances and lighting equipment. These are processed in Liechtenstein, Germany or Belgium. Hazardous materials too are mainly recycled or disposed of in Switzerland; only 300 tonnes or 17 % of the total quantity of pollutants are exported abroad. Some capacitors are sent to Austria for specialist waste incineration, broken glass from Belgian lighting equipment recycling that contain mercury are also disposed of in Belgium, while some wet-cell batteries, CFCs and oil from refrigeration appliance recycling are disposed of in Germany.

Many of the recyclable fractions produced cannot be recycled in Switzerland. Therefore, after primary processing, more than 40 % (around 50,000 tonnes) is directly exported abroad, mainly to other European countries, but also as far away as Japan. Another part, metals for example, also goes abroad via Swiss intermediaries, though, as far as this is concerned, the materials flow database offers no accurate figures. → Fig. 3 shows to which countries Swiss recyclers export their fractions directly. Over 65 % of the exports are to Germany, around 20 % to Austria and around 6 % to Belgium. Smaller quantities, in the region of 0.1 % to 3 %, go to all the other countries.

→ Fig. 4 shows the percentage shares of exported recyclable materials to various countries. Thanks to the short transport distances and the multifaceted recycling infrastructure, large quantities of various different fractions are sent to Germany for recycling. In Austria, Belgium and the Netherlands, it is mainly plastics, along with metals and CR tubes, that are recycled. It is principally metal/plastic composites and printed circuit boards that go to Sweden, though printed circuit boards are also exported to Germany and Austria (albeit in insignificant quantities relative to the other fractions). These valuable fractions are also often sold on in Switzerland before reaching specialist smelters in Germany, Belgium or Sweden. Various different metal fractions are exported to Liechtenstein, Japan, Italy and France.

Fig. 3: Countries to which fractions from Swiss EE equipment recycling are exported

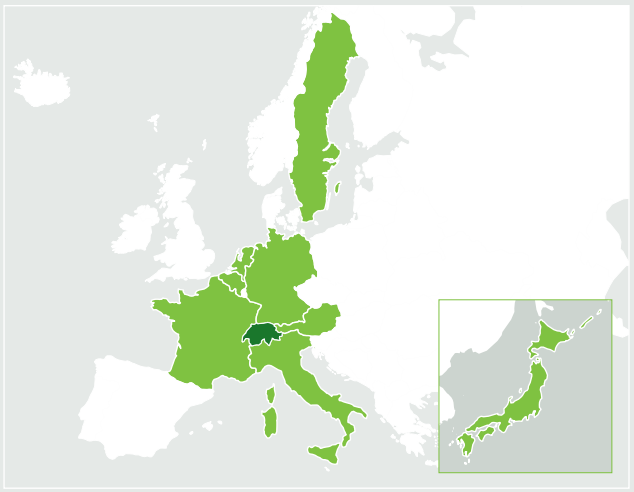
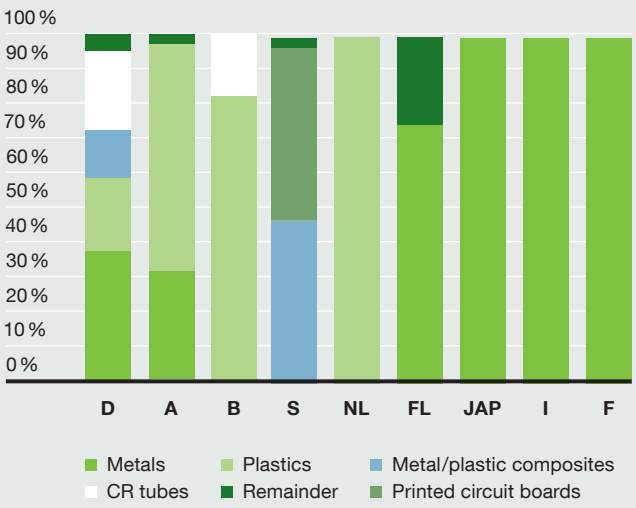


Fig. 4: Percentage share of various exported fractions



Further growth potential in recycling

In all, around 75 % of materials extracted from EE equipment are recycled. As mentioned above, the various metal fractions which go directly from the EE equipment recyclers to the metals trade without further processing and then on to the smelters account for the largest recycling fraction. The share of recyclable plastics has risen sharply in recent years and in 2011 was around 70 % (see also the amount on page 16). High-value metal/plastic composites are separated abroad in costly processes into pure metal and plastics fractions. In this way, the metals and, in certain cases, also the plastics can be recycled. How high the effective recycling rate is cannot be determined due to the way existing data are processed since metal and plastic shares are very different depending on their particular primary processing. Glass fractions can be recycled (screen glass, flat glass and recycled glass from lighting equipment), as can cables and printed circuit boards. Thanks to improved mechanical sorting processes and the targeted promotion of recycling – plastics fractions, for example – the recycling ratio can be increased even further in the future.

Growing recycling of refrigeration appliances

In 2011 in Switzerland, a total of 16,800 tonnes of refrigeration, deep-freeze and air-conditioning appliances were recycled. The size of the refrigeration appliance market shows an increase of 1,000 tonnes or 6 % compared with the previous year. The saturation expected in 2009 has so far yet to be observed. The share of equipment processed abroad amounts to a constant 3 % as in previous years. In 2011 there were four facilities able to process equipment to stage 1 (extraction by suction of refrigerants from compressors) and stage 2 (extraction of the propellant from polyurethane insulation foam).

Different development patterns for equipment with CFCs

→ Fig. 5 shows the downward trend in compressors using CFCs that was detected in 2003 and is still continuing. The share of compressors containing CFCs was still 65 % in 2011. At the same time, the share of compressors containing HCs increased (to 31 %). Since, with the phasing-out of CFC refrigerants, an interim solution in the form of ozone-friendly PFCs (R134a) became available, this downward trend started later than with the propellants in polyurethane foam insulation. Absorption cooling systems containing ammonia continue to account for a 4 % share.

The decline in CFC propellants in polyurethane insulation foams in appliance housings was still evident at the end of the millennium. Since 2009 an even stronger downward trend in CFC-foamed appliances was apparent, a trend which continues today. In 2011 this share still amounted to only 52 % and, in the 2012 recording year it is anticipated that an equilibrium between CFC and HC (cyclopentane) appliances will be achieved. Thereafter, HC-foamed housings will account for the majority of refrigeration, deep-freeze and air-conditioning appliances in stage 2 processing → Fig. 6.

Fig. 5: Development of types of refrigerant and propellant on the old-appliance market

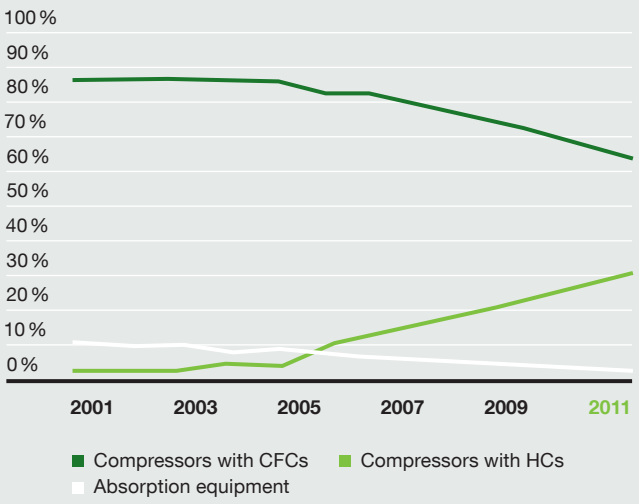
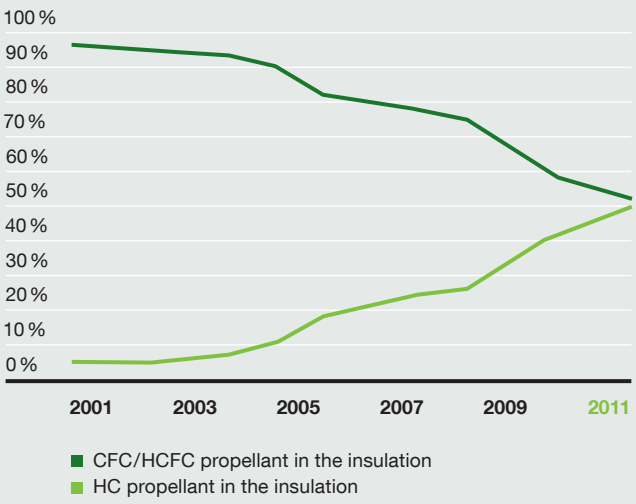


Fig. 6: Development of propellant use in refrigeration, deep-freeze and air-conditioning appliances



Quantity of extracted refrigerant unchanged (stage 1)

→ Fig. 7 shows the quantity of refrigerant recovered from cooling circuits (CFC/HC mixture). While in the 96/97 recording year this still amounted to almost 130 g, since 2002, it has fluctuated around an average of 100 g. The quantity of oil, which represents an indicator of the efficiency of the suction process, originally experienced somewhat greater fluctuations. In recent years it has moved around a more constant level. In 2011 the recovery of 212 g of oil per appliance was achieved.

Longstanding downward trend in CFC-foamed appliance housings (stage 2)

CFC (R11) has double the specific gravity of HC (cyclopentane). Since, after processing the equipment, both propellants are unseparated and exist as a mixture, and since the share of HC equipment is on the increase, the quantity of propellant recovered per kg of polyurethane insulation foam is tending to decline. The recovery of 60 g of propellant per kg of polyurethane insulation foam achieved in 2011 also confirms the longstanding downward trend in CFC-foamed appliance housings on the output side. Short-term increases in recovery in 2005 and 2009 do not contradict this trend but are caused by the commissioning of new processing facilities with higher performance. → Fig. 8 shows the performance indicators measured since the 1993/94 recording year.

Fig. 7: Recovery of CFC/HC and oil from cooling circuits (stage 1)
Quantity in g per appliance

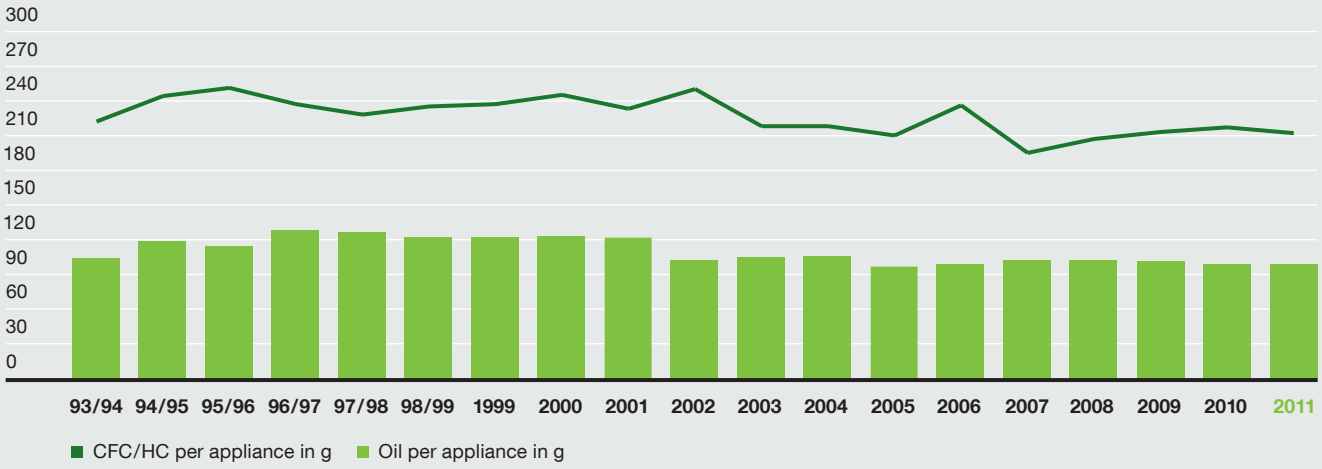
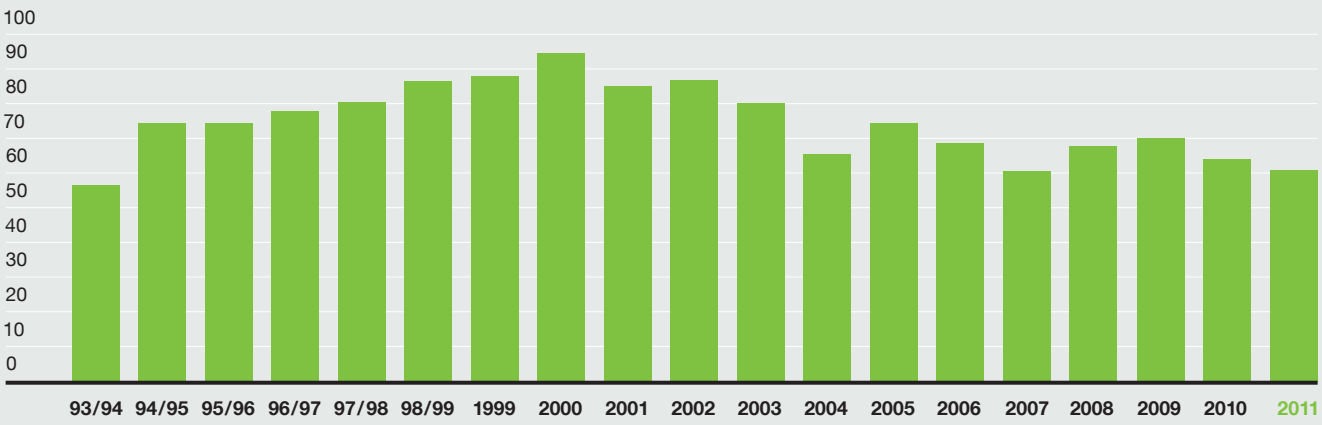


Fig. 8: Recovery of CFCs/HCs from polyurethane insulation foam (stage 2)
CFC/HC mixture in g per kg of insulation foam



Finally, →Fig. 9 shows the downward trend established in 2000, which has experienced sporadic blips due to performance improvements (vertical columns). Above the dotted line after 2011 are forecasts for the coming years. Basically the forecast is moving in the direction of a minimum recovery of around 40 g per kg of polyurethane foam at some point. This forecast is based on the assumption that, in the long term, end-of-life CFC appliance housings will disappear from the old-appliance market altogether.

In general the 2011 materials flows showed an altogether gratifying development in that the emphasis has shifted increasingly towards the sustainable recycling of reusable materials and increasingly away from the disposal of pollutants.

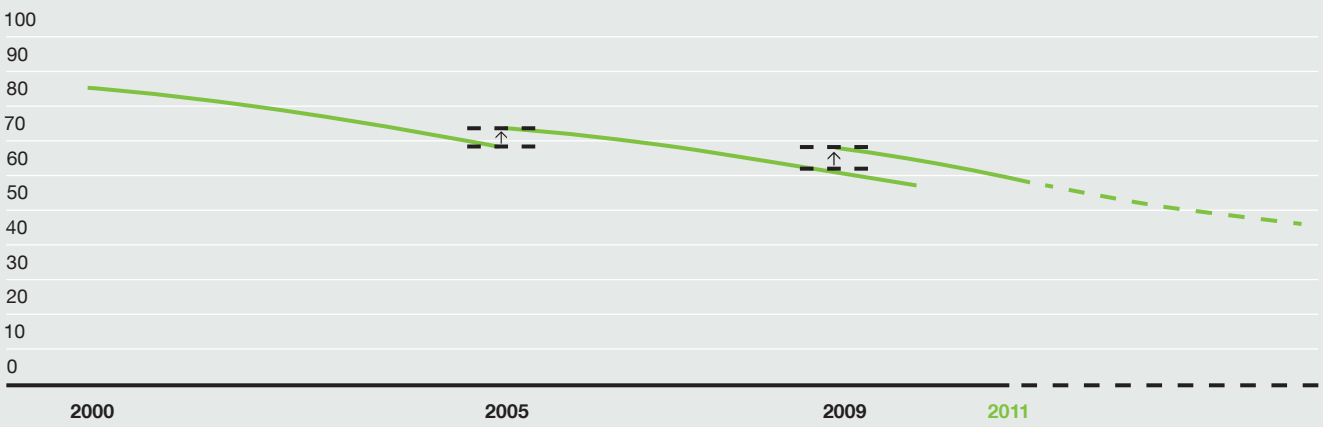
Esther Müller

After training as an environmental engineer focusing on resource and waste management at the ETH (Swiss Federal Institute of Technology) in Zurich, Esther Müller worked as project leader in the field of polluted areas at BMG Engineering AG in Schlieren. Since 2007 she has worked on the scientific staff of the "CARE" group (Critical Materials and Resource Efficiency) at Empa in the field of analysing and modelling national and global material flows in connection with particularly promising technologies for the future and the materials involved. Since 2012 Esther Müller has been working on her dissertation.

Geri Hug

Following chemistry studies and a dissertation at the Institute of Organic Chemistry at Zurich University Geri Hug became a member of the scientific staff and project leader at Roos+Partner AG in Lucerne. In 1994 he became a partner and, from 1997, also managing director at Roos+Partner AG. Alongside consulting, Geri Hug produces short reports and risk analyses as per StFV, operational and product-based ecological assessments and validates environmental reports. Geri Hug is an inspector at SENS in the field of electrical and electronic waste management.

Fig. 9: Confirmation of the trend and forecast of propellant recovery (stage 2)
g CFCs/HCs



Increase in flat screen recycling

The technological changeover from flat screens with background illumination containing mercury to those with LED background illumination has led to a need for collection, recycling and disposal by skilled professionals of a fast-growing quantity of devices with screens that, by now, have fallen into disuse. Flat screens are a source of recyclable materials but also of pollutants.

LCD flat screens, installed in TV sets and desktop or laptop computers which were on sale roughly between 1999 and 2010, used small fluorescent tubes containing mercury as background illumination. Since 2011, to all intents and purposes, only devices with LED background illumination have been on the market. The quantity of LCD devices taken in has increased continuously since 2005, something in which the steady fall in prices and the consequent increase in sales also played a part. Recyclers have quickly implemented the necessary measures. At the start, the only available means of disposal were the manual dismantling of the devices or their incineration with municipal waste. Since September 2011 at SOVAG in Rubigen and since March 2012 at Griag Glasrecycling AG in Werder in Germany, these devices can also be processed mechanically. SWICO Recycling has investigated the subject of the future disposal of flat screens in a study published in March 2011.

The mercury content of background illumination

According to specialist literature, the mercury content per small fluorescent tube amounts to 3.5–5, or 5–10 mg of mercury (Hg), depending on the source. Investigations by Empa commissioned by the Federal Office for the Environment (BAFU), on the other hand, revealed significantly smaller contents of 0.6–1.6 mg Hg per tube, with most of the mercury present in the form of gas → Table 1. It is well known, however, that conventional LCD TV screens contain a large number of these tubes so that, in many cases, more than 20 mg of mercury per TV screen device has to be disposed of. By way of comparison: energy-saving bulbs contain 4–8 mg of mercury. On the basis of the latest figures, the total quantity of mercury in flat screens to be disposed of – expected to peak around 2014 – will reach 15–20 kg per annum. Printers, scanners and copiers may also contain small fluorescent tubes with diameters of up to 1 cm containing mercury. These have to be removed manually from the devices since, to date, no means of mechanical processing is possible.

Table 1: Mercury content of the background illumination of various LCD screens

	LCD laptop		LCD PC monitor		LCD TV	
	mg/CCFL	%	mg/CCFL	%	mg/CCFL	%
Hg gas	0.6	97	0.9	90	0.9	55
Hg solid	0.02	3	0.1	10	0.7	45
Hg Total	**0.6**	**100**	**1.0**	**100**	**1.6**	**100**

Source: BAFU/Empa 2011

Recyclable indium: a rare metal

While, in terms of pollutants, the focus of attention is mercury, indium (In) is also significant in terms of recycling. Indium is used in older as well as more recent devices because it is transparent and, in very thin layers, electrically conductive. Due to its low concentration in the earth's crust, indium is a rare metal. It is also used in photovoltaic devices. Previously, in Switzerland, indium was not extracted from flat screens. The possibilities of extracting indium are to be investigated in a SWICO Recycling project. Investigations into the interim storage of LCD panels are also underway, with a view to extracting the indium at a later stage if need be.

According to analyses undertaken in Germany in 2011, a quantity of around 0.8 mg of indium per m^2 can be assumed per screen. Consequently, the indium quantities indicated in the SWICO study have to be corrected upwards by a factor of 2. Estimates based on computer model calculations show that the maximum quantity of indium available for disposal in 2017 will be around 230 kg. By contrast, the maximum indium quantity in flat screens still in use in 2015 will amount to around 1 tonne.

Table 2: Mercury residues in the fractions from the mechanical processing of flat screens

Fractions	Particle size (mm)	Proportion (%)	Hg (mg/kg)	Hg yield (mg/h)
Metals (magnetic)	–	32.1	< 0.05	8
Finest fraction	< 3	10.8	6.95	375
Fine fraction	3–8	4.3	0.66	14
Medium fraction	8–11	21.1	0.64	68
Coarse fraction	11–15	14.9	0.14	10
Oversized particles	> 15	16.8	0.05	4
Dust/luminous coating	–	< 0.1	424	< 212
TOTAL				**< 691**

Source: SOVAG 2011

Table 3: Comparison between the disposal options for flat screens

	Manual dismantling	Mechanical processing
Final fractions	Pure fractions (metals, plastics, printed circuit boards, background illumination, etc.)	Mixed fractions (metals/plastics/printed circuit boards; in different particle sizes) magnetic metals, dust fraction
Mercury extraction	Small losses in subsequent processing through exhaust fumes and residues in the final fraction	Losses through exhaust fumes and residues in mixed fractions and in the dust fraction
Indium extraction	From pure fractions (LCD panels)	From mixed fractions (fractions from subsequent sorting)
Costs	Dismantling costs – income from the sale of pure fractions + disposal costs	Handling costs + cost due to subsequent sorting – income from the sale of final fractions

Source: Empa 2012

Manual dismantling or mechanical processing?

The rules governing emissions limits for dust and mercury can be complied with in the mechanical processing of flat screens. Excluding dust and fine particle fractions, which require special disposal procedures, residues of mercury in the final fraction amount to less than 1 mg/kg → Table 2.

Using data from SUVA (Swiss National Accident Insurance Fund) and experience in manual dismantling, it is evident that, with appropriate dismantling techniques, the results will be significantly below the Maximum Workplace Concentrations (MAK).

In the opinion of the inspectors at SWICO Recycling, both types of procedure are permissible. They differ, however, in one or two respects → Table 3.

New processing regulations

The processing regulations for recycling operations were updated on 12 April 2012, taking account of the existing disposal options. Among other things, the disposal of entire screens in waste incineration plants was banned. As far as fractions resulting from mechanical processing are concerned, limits for the mercury content in metal and mixed fractions of 10 mg/kg and in glass fractions of 5 mg/kg were laid down in line with the limits for lighting equipment. Thus the way has been decisively paved for sustainable and environmentally friendly recycling.

Heinz Böni

Heinz Böni is a specialist inspector at SWICO Recycling and SENS and took on the running of the Technical Inspectorate at SWICO Recycling in 2009. Since 2011 he has run the "CARE" group (Critical Materials and Resource Efficiency) of the technology and society department at Empa as well as being interim department manager of the technology and society department at Empa engaged in research and services in the field of sustainable resources management. Before his appointment at Empa, he was an advisor and planning engineer in the field of waste management for 10 years.

Increase in plastics recycling

Plastics play an ever more important part in the recycling of electrical and electronic equipment. Here the focus is principally on recycling the materials, although it is critical that this does not just amount to the transfer of pollutants to new products.

On average, 20 % of electrical and electronic equipment is plastic and this is a growing trend. Plastic recovered from the dismantling of electrical and electronic equipment can be re-used as a material or used to create energy. From an environmental point of view, the re-use of the material is to be welcomed, as long as it does not involve the transfer of pollutants to new products. According to a study commissioned by the European Association of Electrical and Electronic Waste Take Back Systems, the WEEE Forum, heavy metals (lead, cadmium, chromium VI and mercury) as well as brominated fire retardants (polybrominated biphenyls [PBBS], polybrominated diphenyl ethers [PBDEs]) are particularly important here. The maximum permissible concentration of these pollutants in plastics as used in electrical and electronic equipment has been laid down in the EU RoHS Directive since 1 July 2006 and in the Swiss Chemical Risk Reduction Ordinance (ChemRRV).

Adaptation to European law

In the context of the on-going revision of ChemRRV, adaptations are also being proposed concerning brominated fire retardants. Preparations and new products which are wholly or partly created from recycled materials or from materials derived from waste processed for re-use are only permitted in future to contain 0.1 % each of tetra-, penta-, hexa- or heptaBDE. 'Homogenous' materials such as plastics in electrical and electronic equipment are only permitted in future to contain maximum concentrations of 0.1 % by weight for lead, mercury, hexavalent chromium, polybrominated diphenyl ethers (including decaBDE) and polybrominated biphenyls and of 0.01 % by weight of cadmium.

Material recycling preferred

The currently on-going revision of ORAREEA (the Ordinance on the Return and Recycling of Electrical and Electronic Appliances) envisages that plastics are subject to material recycling. In past years the share of materially recycled plastics from electrical and electronic equipment has increased. In the course of 2007 even less than 40 % of material described as 'plastics' in the materials flow data sheets was supplied to customers who process plastics (i.e. those who do not separate re-usable plastics[1)] from those containing pollutants) and then carry out material recycling. In 2011, it was almost 70 %, which represents almost 16,000 tonnes of plastic. However, as a result of the processing, only part of the plastics supplied was actually materially recycled[2)]. A further increase in the proportion of materially recycled plastics could be achieved by diverting the non-polluting plastics share of the 'plastics' fractions which today go for energy-producing recycling or to waste (2011: around 7,000 tonnes or 30 %) as well as 'plastics/metals mixtures' (2011: total around 14,000 tonnes) to material recycling. To prevent cross-contamination by the contents of other WEEE components, among other things, an enhanced selective manual separation of plastics prior to mechanical processing of WEEE equipment should be tested. According to the study commissioned by the WEEE Forum and mentioned earlier, contamination by pollutants covered by ChemRRV is generally at its lowest level in composite materials from flat screens and large domestic appliances including refrigeration equipment. Furthermore, SENS and SWICO Recycling are promoting the view that the recycling of plastics can be carried out in a more sustainable and environmentally friendly way by an increase in material recycling.

1) Including 'plastics from refrigeration equipment' and 'PUR plastics mixtures from refrigeration equipment' fractions. Other plastics also add up in the 'plastics/metals mixtures for processing' and 'plastics/metals mixtures for incineration' fractions.
2) At a rough estimate this is about 50 % of materials supplied.

Patrick Wäger

After chemistry studies and subsequent dissertation at the ETH (Swiss Federal Institute of Technology) Zurich, Patrick Wäger was an environmental advisor to Elektrowatt, Zurich, for two years. Since then he has been on the scientific staff at Empa, engaged among other things, on projects on sustainable ways of dealing with natural resources. Furthermore, he is a specialist inspector for SENS and SWICO Recycling and committee member of the International Solid Waste Association (ISWA) and the Swiss Academic Society for Environmental Research and Ecology SAGUF.

Mobile phone goldmine

When it comes to mobile phones, Switzerland has one of the world's highest recycling rates. However, more than half of all old mobile phones still remain unused in Swiss households. Greater efforts should be made to exploit this potential. Mobile phones should not be underestimated as a source of various precious and other metals, which makes them even more interesting from the point of view of sustainable recycling.

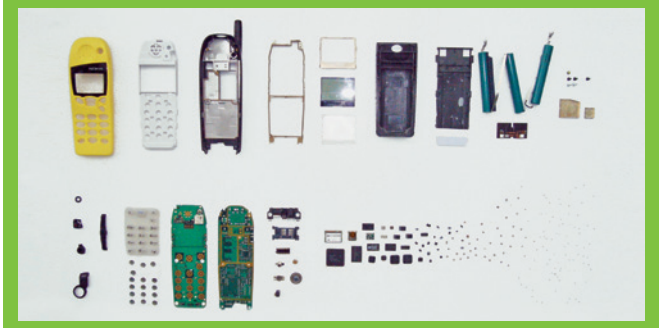
According to the latest statistics (BFS 2009), mobile phones are the most common communications devices in Swiss households after TV sets → Fig. 2 and → Fig. 3. More than 90 % of households have a mobile phone, and 50 % even have several. Since 2000 this figure has increased by more than 50 %. Smartphones have boomed since 2009 and worldwide quarterly sales have more than doubled to over 110 million devices in just three years. Today, in Switzerland, according to the White Paper, more than 3.6 million mobile phones are sold annually. Around 20 %, in terms of sales volumes, reached the return points in 2011. On the one hand, this can be seen as a major achievement given that worldwide recycling rates are only 3 %. On the other hand, it also means that an estimated 8 million obsolete and unused mobile phones have accumulated in Swiss households. In Europe, according to a survey by Nokia, 44 % of old mobile phones are lying around in drawers, 25 % are passed on to family members and friends and around 16 % are sold privately.

Gold, silver and other precious metals

Around 40 % of the total weight of a mobile phone can be recycled. An estimated 50 % of the total weight of a mobile phone can be processed to produce energy, for example to supply pyrometallurgical recycling processes with energy. As a result, only 10 % is waste. What makes the recycling of mobile phones even more interesting over the longer term is the fact that they contain a high concentration of recyclable precious and other metals such as gold, silver, lithium and copper.

The mobile phone in → Fig. 1. was meticulously analysed on the 'Tecday' at the cantonal school in Trogen in the context of a school workshop – 'My mobile weighs more than a tonne' – under the auspices of Empa (Swiss Federal Laboratories for Materials Science and Technology). In the process, the phone's 'ecological backpack' was also ascertained. As shown in → Table 2, more than a tonne of material has to be moved and processed to produce a device weighing only 170 g.

Fig. 1: Picture of a disassembled mobile phone



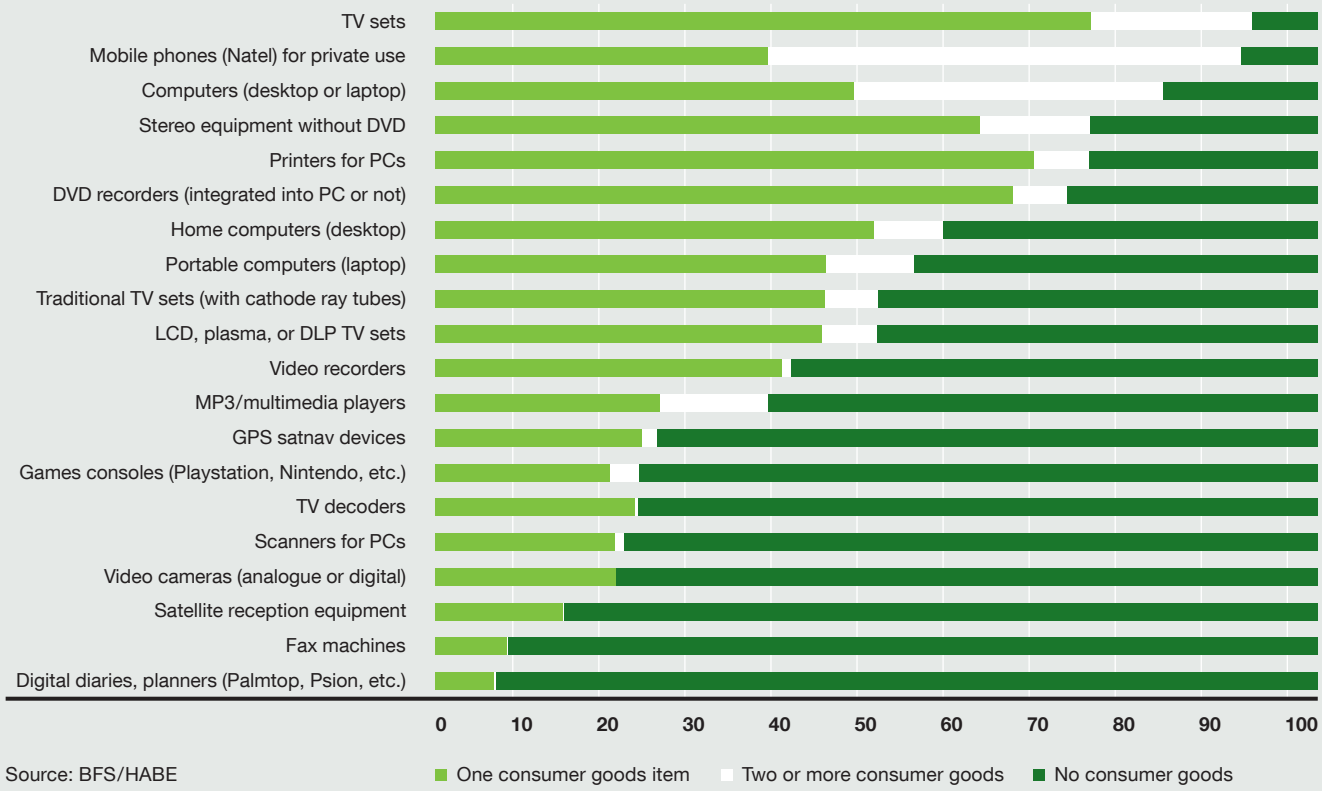
The scarcely visible dots, bottom right, are surface-mounted components which often contain critical metals in high concentrations.

Table 1: Growth in the number of returns as well as composition and weights of the fractions produced 2009–11 (from SWICO Recycling annual reports). Missing data due to changes in the recording system.

Year	Number 1,000	Average weight (kg)	Metals (t)	Plastics (t)	Metal/plastic mix (t)	Cable (t)	Glass and/or LCD module (t)	PCBs (t)	Hazardous materials (t)	Other [1] (t)	Total (t)
2011	457	0.14	10.38	22.83	–	–	3.35	14.45	12.92	–	63.93
2010	382	0.13	–	19.36	–	–	3.48	10.45	17.42	–	50.72
2009	327	0.13	23.48	9.70	5.49	1.01	0.09	0.82	0.45	1.47	42.50

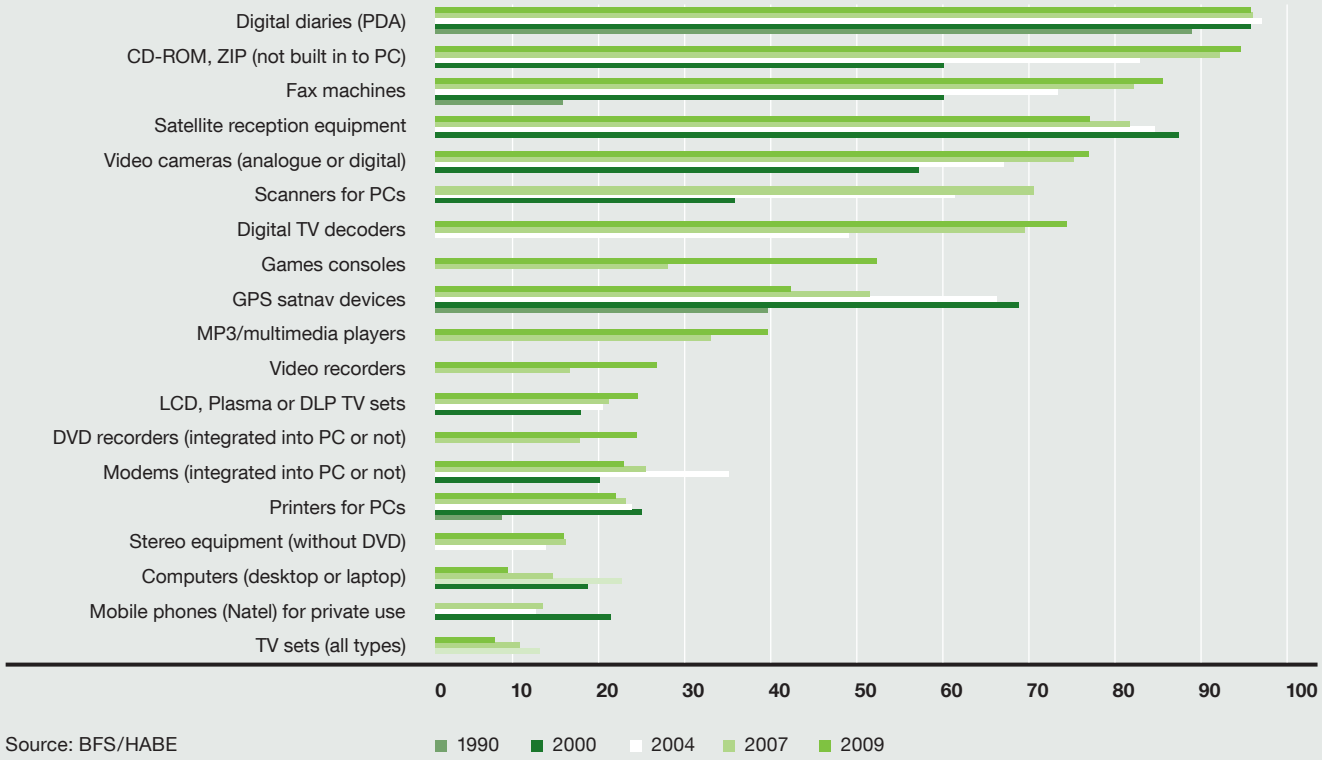
[1] Packaging and other waste

Fig. 2: ICT (Information and Communications Technology) equipment in Swiss households by appliance, 2009
Households with equipment in %



Source: BFS/HABE

Fig. 3: ICT (Information and Communications Technology) equipment in Swiss households, development 1990–2009
Households with equipment in % (minimum 1 consumer good)



Source: BFS/HABE

Table 2: Compilation of materials required [t/t], energy consumption [MJ/kg] and environmental pollution in eco-indicator points/kg

Material	Content	'Backpack'	Materials required						Energy consumption		Eco-indicator	
			Primary			Secondary			Primary	Secondary	Primary	Secondary
	(g)	(g)	Abiotic material	Water	Air	Abiotic material	Water	Air				
Plastic	60.75	13,061.25	4	207	4				99		0.49	
Epoxy resin	7.06	2,188.17	14	290	6				83		0.41	
Glass fibre	4.87	501.40	6	95	2							
Flat glass	4.75	76.00	3	12	1				15		0.09	
Iron	4.16	923.52	14	205	3	1	59	1	73	68	1.23	1.22
Aluminium	13.43	14,718.95	37	1,048	11	1	31	1	194	24	0.90	0.17
Copper	19.06	13,688.45	349	367	2	2	86	1	60	28	15.65	0.63
Gold	0.04	126,828.80	540,000	2,000,000	500,000				312,776	7,453	19,772	43.24
Silver	0.24	11,561.50	7,500	30,000	10,000				6,738	128	252	0.74
Silicon	0.87	14,773.00	2,000	10,000	5,000				1,591		7.17	
Lithium	1.17	42.04	6	20	10				415		1.16	
Manganese	9.93	2,114.30	17	194	2				0.25		0.01	
Nickel	1.17	484.64	141	233	41				187	15	6.04	0.09
Graphite	9.34	3,101.68	20	306	6				68		0.18	
Electrolytes	11.68	1,623.24	3	134	2				39		0	
Other	21.25	962,741.87	15,000	30,000	300	5,000	10,000	100	13,476.02	6,738.01	503.01	251.51
Total	**169.77**	**1,168,428.82**										

Source: MIT value table (as at 14 July 2011): material intensity of materials, energy sources, transport services and foodstuffs Ecoinvent v2.2, Empa estimations

Potential for the recovery of metals

From the compilation of materials and the quantities of mobile phones in use, it is possible to estimate the potential for the recovery of the metals they contain → Table 3. Due to the large number of devices in existence, even the very small amounts found in individual mobiles add up to something extremely valuable. Thus returns in 2011 yielded almost 20 kg of gold and the stock of unreturned devices would yield in excess of 336 kg.

At the moment, due to the extremely compact construction of mobile phones and the high concentration of rare technical metals they contain, the best means of processing old devices is relatively simple: after the removal of the battery, the devices are taken straight to a specialist smelting plant where they are smelted with other recycling products to extract as many metals as possible. As mentioned above, the plastic serves as a potential energy source in such a way that no additional fuel is required.

Table 3: Quantities of selected metals which can potentially be extracted.

Content	Content (g/unit)	Returns 2011 (kg)	Swiss stock 2011 (kg)
Copper	19.065	8.713	152.520
Aluminium	13.430	6.138	107.440
Manganese	9.926	4.536	79.408
Iron	4.160	1.901	33.280
Lithium	1.168	534	9.344
Nickel	1.168	534	9.344
Silver	0.243	111	1.944
Gold	0.042	19	336

Rolf Widmer

Rolf Widmer finished his studies as dipl. El. Ing. (MSc ETH EE) and postgraduate NADEL (MAS) at the ETH (Swiss Federal Institute of Technology) in Zurich. He undertook research for several years at the quantum electronics institute at the ETH and today works in the Technology & Society Lab at Empa, the materials research institute at the ETH. Currently, Rolf Widmer leads projects in the areas of electronic waste management, especially in connection with closed material cycles in the field of electromobility. His particular interest is the extraction of rare technical metals to be collected from the growing volume of 'urban mines'.

Pan-European harmonisation of recycling requirements

The WEEE Forum, the European association of currently 41 collective take-back and recycling systems for electrical and electronic equipment, started a project in January 2009 which should lead to the harmonisation of the technical requirements for the processing of electrical and electronic equipment. On 1 April 2011, the European WEEELABEX standard was adopted.

In paving the way for the establishment of a common standard, representatives from SENS, SWICO Recycling and SLRS have collaborated on various commissions. On 1 April 2011, the European WEEELABEX standard was adopted and, since then, preparations for its implementation have been underway. As part of this process, the decision-making structures have been defined and the required documents specified together with how they will be created and acted upon. Thus, for example, report templates for the operational inspections that take place annually are being developed and checked during pilot audits. Furthermore, deliberations are underway to determine how the financial flows will be created.

From 1 January 2013, the WEEELABEX standard is to be implemented by SENS, SWICO Recycling and SLRS, together with 12 other systems in Italy, Spain, France, Belgium, Romania and Germany. Other systems will follow in 2014 or 2015.

What rules are contained in the WEEELABEX standard?

The WEEELABEX standard comprises three complementary standards for the collection, logistics and processing of old electrical and electronic equipment. Critical for recycling is the processing standard. This establishes which general and equipment-specific technical requirements will be imposed for recycling. Equipment-specific requirements are prescribed for the flat screen, CR tube screen, lighting equipment and refrigeration appliance categories.

In the standard, 31 terms are defined. Within the general requirements, administrative, organisational and technical requirements will be differentiated → Table 1. In the general part of the WEEELABEX processing standard as an appendix are the pollutants extraction guidelines and the provisions covering pollutant extraction monitoring. Furthermore, the requirements regarding the carrying out of batch tests and for the determination of recycling and recovery rates are to be set out.

Table 1: Requirements of the WEEELABEX standard (extract)

Administrative/organisational requirements
Compliance with legal provisions: obligation to provide evidence of compliance with the relevant EU laws
Management principles: existence of a (not necessarily certified) management system for health, safety, environment and quality; obligation for continuous improvement
Technical and infrastructure requirements: existence of a suitable infrastructure, including protection against unauthorised access; insurance cover
Training: obligation to provide evidence of training for all staff; easy access to education and training material
Downstream monitoring: obligation to document successive processing stages right up to the waste point
Preparation for re-use: testing equipment and approval responsibility; compliance with legal requirements
Transport: no export to countries where processing compliance with WEEELABEX is not assured
Technical requirements
Processing: duty of care during processing to avoid the emission of pollutants into the environment
Appliance storage: storage only on non-porous surfaces with weatherproof covering for certain appliance categories
Hazardous materials extraction: extraction of components containing pollutants to comply with the WEEE Directive; ban on dilution; precautionary principle
Checks on pollutant extraction: obligation to monitor extraction performance by the input/output analyses of fractions, benchmark analyses
Further processing: ban on mixing hazardous waste
Storage of fractions and components: prevention of the release of pollutants into the environment; weatherproof storage of components containing pollutants
Recycling and recovery: attainment of recycling and recovery rates as per the WEEE Directive; obligation for batch tests every 2 years per processing category
Removal of fractions: regulations on the accumulation of deposits
Documentation: obligation to keep records on processes, procedures, risk evaluation, etc.

Source: WEEE Forum

What changes does the WEEELABEX standard bring about?

To a great extent the WEEELABEX standard dovetails with the existing technical rules of SENS and SWICO Recycling, for which they have also provided a basis. There are differences in the area of the requirements on re-use (here SENS and SWICO Recycling have no provisions), in storage (SENS and SWICO Recycling have stricter rules), in pollutant extraction monitoring (WEEELABEX also demands a benchmark for printed circuit boards), in documentation obligations (WEEELABEX has somewhat more extensive requirements than SENS and SWICO Recycling) and in the processing of cathode ray tube screens (WEEELABEX requires a procedure for detecting yttrium). Since the WEEELABEX standard is more far-reaching than the existing technical rules of SENS and of SWICO Recycling in some areas, the efforts involved in operational monitoring tend to be greater.

Implementation of the standard will involve a few organisational changes → Table 2. The WEEELABEX organisation will set the rules and become the leading body for implementation. It will be provided with a supervisory committee and an advisory committee. Changes to the standard, or to its documentation, can only be undertaken by the WEEELABEX organisation.

The standard provides a guarantee that recyclers recognised by WEEELABEX are all measured by the same yardstick. There will be no further need for several audits of the same recycler by different systems, something which at the same time also improves the opportunity for a recycler audited by WEEELABEX to operate outside his national sphere of activity.

The ultimate objective is a generally binding standard

The WEEELABEX standard is a voluntary standard which only imposes obligations on participating systems. Consequently there is a certain risk of distorted competition principally in countries without collective systems (Germany, for example) or with several collective systems which do not wish to implement WEEELABEX. The intention, however, is to convert the voluntary WEEELABEX standard at a later stage via CENELEC, the European Committee for Electrotechnical Standardization, into a generally binding standard, to which in the end all recyclers in Europe will be subject. The relevant groundwork is already in hand. SENS, SWICO Recycling and SLRS are active participants in this process, since a pan-European agreement on recycling requirements for electrical and electronic equipment is entirely in line with their interests and objectives.

Table 2: Proposed implementation of the WEEELABEX standard at national level

Recycler: Declaration of conformity with the WEEELABEX standard prior to operation monitoring
WEEELABEX system: • Choice whether to implement the standard independently at national level or jointly with neighbouring countries where the same language is spoken • Right to submit proposals for WEEELABEX auditors and group leaders • Appointment and remuneration of WEEELABEX auditors • Recognition of the results of a WEEELABEX audit carried out by another WEEELABEX system • Option of sending an observer to an audit
National or regional audit groups: WEEELABEX auditors create a national or regional audit group to be run by a group leader. The nomination and appointment of the group leader is done via the WEEELABEX office. The group leader maintains a link with the WEEELABEX office independent of any of the participating systems. He supervises and leads the auditing process.
WEEELABEX auditor: • Must carry out the specified requirements • Must complete a WEEELABEX training programme • Duty of confidentiality vis-à-vis the recycler

Extract, as at April 2012, source: WEEE Forum

What is the WEEE Forum?

WEEE stands for 'Waste Electrical and Electronic Equipment'. The WEEE Forum is a European non-profit organisation based in Brussels. It consists of 41 WEEE recovery systems and was set up in April 2002. The objective of the WEEE Forum is to offer its member organisations a platform for the exchange of ideas and initiatives concerning measures aimed at optimising the processing of electrical and electronic equipment. The complete WEEELABEX standard can be downloaded from the WEEE Forum website: → www.weee-forum.org/weeelabexproject

Heinz Böni

After training as Dipl. Cultural Engineer at the ETH (Swiss Federal Institute of Technology) Zurich and postgraduate studies in sanitary engineering and water protection (NDS/EAWAG), Heinz Böni worked on the scientific staff at EAWAG Dübendorf. After becoming project leader at the ORL institute at the ETH Zurich and with UNICEF in Nepal, Heinz Böni took over office management of the Kies+Abfall AG. Then he was co-proprietor and managing director of EcoPartner GmbH. Before taking on the running of the Technical Inspectorate at SWICO Recycling in 2009, Heinz Böni was already an inspector at SWICO Recycling and SENS. Since 2011 he has run the 'CARE' group (Critical Materials and Resource Efficiency) of the technology and society department at Empa as well as being interim department manager of the technology and society department at Empa engaged in research and services in the area of sustainable resources management.

Sustainable collaboration

The implementation of inspections on the recycling and dismantling operations involving electrical and electronic equipment has been delegated to SENS/ SWICO Recycling by the cantons of Zurich, Aargau and Thurgau since 2006. How did this concept originate and what has led to its successful realisation?

Dr. Alois Villiger: The situation was as follows: on one side were the cantons, who were asked because they would have to grant permission for operations involving the disposal of electrical and electronic equipment. On the other side were SWICO Recycling and SENS, which had taken on the supervisory role on the basis of ORAREEA (the Ordinance on the Return and Recycling of Electrical and Electronic Appliances).

SWICO Recycling/SENS and the responsible technical office in the canton of Zurich in particular have kept in close contact for years over the development and implementation of ORAREEA, so the advantages of even closer cooperation were obvious.

Then SENS asked the cantons whether they could envisage a cooperative effort in which SENS/SWICO Recycling would also assume the supervisory role on behalf of the cantons.

From our side, that of the canton of Zurich, we were unable to implement the monitoring functions defined by the legislators as we would have wished because of staff shortages, so we were glad to take up the offer, especially as Article 43 USG (Environmental Protection Act) expressly provides for outsourcing to private organisations, even in the area of monitoring. Our willingness to outsource the supervisory function to SWICO Recycling/SENS is based on positive experiences with similar delegations to private monitoring bodies in other areas over a number of years.

Another reason for this decision was that SWICO Recycling/ SENS has acquired considerable specialist know-how in the collection, recycling, disposal, etc. of electrical and electronic equipment over a number of years, a level of expertise which AWEL lacks in this area.

So we came up with the idea not just of delegating the checking of the correct collection, professional recycling and disposal of electrical and electronic equipment to SWICO Recycling/SENS, but also of making the role more comprehensive and having the implementation of water protection and clean air regulations also monitored by SWICO Recycling/SENS.

Alois Villiger
After being educated as a chemist at the ETH Zurich (Swiss Federal Institute of Technology Zurich) specialising in analytical chemistry, Alois Villiger became an analytical chemist at Empa in St. Gallen. From 1988 he has been a member of the scientific staff in the waste management department of AWEL in various roles and spheres of activity. Among other things, currently responsible for inspecting waste management companies specialising in electrical and electronic waste in the canton of Zurich.

We have developed this proposal further with SWICO Recycling/SENS in collaboration with the canton of Aargau in such a way that, in the end, an agreement can be reached. In this context the basic agreement regulates, on the one hand, the nature and extent of the inspections and, on the other hand, the content and presentation of the ensuing inspection report to the technical office as well as appropriate communication of the annual written activity report which is produced individually for the particular cantons. Furthermore, it governs the key elements of the joint annual meeting which, on the one hand, provides for a discussion of the know-how developed during monitoring and, on the other hand, is seen as a platform for possible issues of understanding as well as for the discussion of specific handling requirements. Then, at the annual meeting, the key points for the following years will be discussed and laid down, for example, recycling or disposal procedures or additional clarifications which Empa is working on for SENS. By means of this exchange, AWEL and SWICO Recycling/SENS will be able to offer one another mutual support in planning for the future.

You have been able to accumulate experience of this sort of delegation over several years. What type of experience has this delegation produced so far?

Since concluding the agreement in 2005 and starting the implementation of the agreement in 2006, we have accumulated considerable experience.

The delegation of operational supervision has borne fruit particularly in dismantling operations which are part of the role of the waste management contractor. In dismantling operations, water protection and clean air issues usually raise no particular points that have had to be subject to discussions and inspections can be readily carried out without the need for a high level of specialist know-how and can therefore be equally readily delegated.

With waste disposal or recycling operations, there is a greater need for the involvement of AWEL. There, delegation makes less sense due to the particular complexity of the waste disposal facility, since specific expert knowledge is needed and, for example, there are additional requirements with respect to possible accidents. We do not usually delegate these sorts of monitoring roles.

Furthermore, it has been shown that good, structured and comprehensive inspections can be made with the use of clear logs and checklists. At the beginning, I was present at various inspections, partly to get an idea there and then of how the inspections are carried out, and partly to acquire first-hand knowledge of the operations and inspection procedures.

In that way I was able to satisfy myself that dealing with operations managers is customer-friendly and that inspections are effectively and efficiently carried out, as we expect them to be.

In parallel to this, delegation also works better for the waste management or recycling operator, since they are only subject to one consolidated inspection, as opposed to formerly when they had several individual inspections by the canton's various technical offices and by SWICO Recycling/SENS. Thus, today, the basic inspections are carried out efficiently by SENS/SWICO Recycling in less than half a day.

Even without that, we have a continuous flow of information about the current situation and inspection results thanks to the inspection logs. Accordingly, we are well satisfied.

Thus the benefit is obvious. On the one hand, we as a canton, together with the operators being checked, save on personnel resources since several inspections are no longer required and therefore less time is spent, because the canton's comprehensive inspection role has been consolidated and carried out by SENS/SWICO Recycling.

On the other hand, the operations are not only structured by the checklist introduced but are also subject to consistent standardised inspections – which was also the wish of the operators at the time of implementation in any case and, in line with their justifiable demands, has now largely been put into practice thanks to delegation.

At the end of an inspection we have feedback on the state of the operation as well as other items on the agenda, which are immediately scheduled for a new inspection. If SENS/SWICO Recycling on-the-spot inspections throw up an abuse of major environmental significance, an immediate report can be made to the canton's responsible technical office, which, in these instances, will take care of determining and implementing the necessary measures.

In summary, how would you evaluate the collaboration between the two systems of SENS and SWICO Recycling?

I judge the collaboration to be a matter of very open team work, where information flows to and from between the partners in a structured manner: for example, this could be in respect of changes at SENS/SWICO Recycling, in waste management, or with a specific recycling procedure, or in respect of a sphere of activity, or a concern of ours which, for example, has certain effects on the inspections – agreements on such matters flow simply and directly within the collaboration.

All in all, it is a very effective and efficient collaborative effort which, in my view, could not be thinned down any further since the delegation is well structured and focussed. At the annual meeting we exchange information, on the one hand, on the current state of things, for example, which operations have been approved by the canton and which are monitored by SENS/SWICO Recycling. On the other hand, we agree when and how these operations should be inspected. This is against a background in which the dismantling operations are inspected every two years, while waste management contractors and recyclers are inspected annually. The event windows for inspections are determined jointly and the canton is then asked whether it wants to send its own technical representatives along on individual appointments. Whether that happens or not, the canton receives the individual inspection logs after each inspection.

With the annual activity report, each canton has the opportunity to access an overview of the entire year. For this reason, the year as a whole, together with individual positive or negative results, is subject to review, experiences are discussed and opportunities for potential optimisation and future system requirements are agreed at the annual meeting.

In my view, not only does the whole structured operation work well but so too do communications and the regular exchange of information between partners.

What are your main concerns and expectations for future collaboration?

The current high level of quality and effective and good co-operation must be maintained and continued as it has been hitherto. We are satisfied that this is going to happen.

The revision of ORAREEA is upon us, which, this year, is in the consultation process and then will come into force in 2013 or 2014. At present, I cannot gauge how and to what extent the revision will affect the collaboration. As the case may be, we shall see whether certain adjustments are required, which, however, we shall be able to agree with SENS/SWICO Recycling at the proper time.

In any case, it is also important, if not essential, that close cooperation is maintained and promoted between all system operators in the future, since it is entirely possible that, following the ORAREEA revision, other system operators will come on the market. In that event I would certainly propose the SENS/SWICO Recycling inspection system to them and recommend that a corresponding arrangement of delegation and collaboration be agreed with them.

How do you see the future as far as the disposal of electrical and electronic equipment is concerned?

Here I would like to step away from specific focus on the industry solution and answer in general terms about the whole recycling industry. Here the desire exists to maintain or, if possible, to increase the large quantity collected, which is impressive on a pan-European level. In this regard, there are some key elements that have already been tackled such as, for example, the efforts of SWICO Recycling to increase the recycling rate of mobile phones.

Then it is certainly also a matter of maintaining the high standard of waste management and, where possible, improving on it even further. Here too, we are European leaders and for that reason we can make a significant contribution to the WEEE committee. Accordingly, we should also go on working in this area at a high level and with great commitment.

Furthermore, I hope that the ORAREEA revision mentioned above leads, on the one hand, being able to get to grips more comprehensively with the unfortunate theme of 'free-rider' and, on the other hand, that the state of technology can be jointly developed further. In my view, that is something which, until now, has been somewhat suboptimal, in that SWICO Recycling/SENS has a tendency to develop technical fact sheets autonomously with the European associations in the relevant committees without the Confederation or cantons being able to have any influence or standing. In the course of the ORAREEA revision it has been established that future waste management standards will be determined in joint agreements between the authorities and the partners concerned. That represents an important opportunity that we must also be sure to use appropriately.

One last point is a look at the critically important subject of waste and resources. Here we must vigorously address the issue of the technical opportunities which are available to us for thoroughly and efficiently extracting the rare metals which are present in all modern electrical and electronic equipment. Accordingly, this point is covered in the draft ORAREEA revision.

Dr Alois Villiger, we are very grateful to you for this conversation.

Introducing AWEL

The Office of Waste, Water, Energy and Air (AWEL) operates as part of the canton of Zurich's building department to ensure that environmental pollution due to human activities – even in a growing economy – is reduced to an environmentally compatible level and that a sustainable means of dealing with natural resources can be fostered.

Batteries and capacitors: quantities known

The availability of solid data is indispensable for the continuous improvement and expansion of the recycling of EE equipment. Thus, for more than 10 years, SENS has been collecting data on materials flows. Now SENS has had the data comprehensively analysed and benchmarks established for batteries and capacitors in EE equipment.

To comply with technical regulations, recyclers in Switzerland are obliged to remove and make separate records of capacitors (above a certain size) and batteries collected from EE equipment. This sorting can take place prior to or after arrival at suitable facilities as well as during mechanical processing. In both cases it is a manual activity in which the capacitors and batteries are removed by hand from the waste stream. All recyclers supply inspection bodies with data on the quantity of batteries and capacitors removed annually. On the basis of these data the inspectors are able to check how well one recycler removes the devices in comparison with other recyclers. To ensure the reliability of these figures and to create a solid basis for the further expansion of sustainable recycling measures, SENS has commissioned the Environmental Chemical Office to analyse the data from the last ten years of materials flow records[1)].

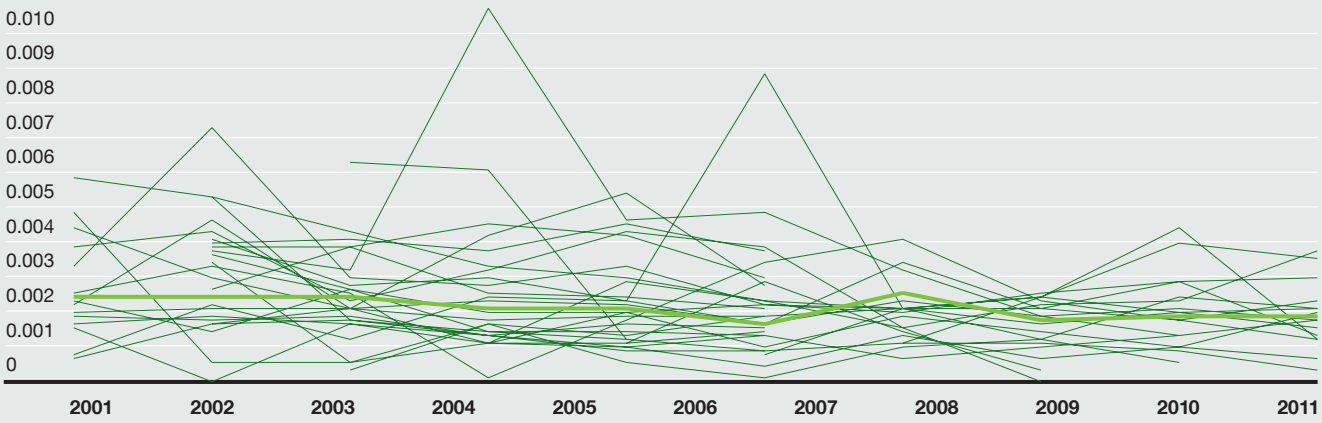
[1)] The complete report can be obtained from the authors: d.savi@umweltchemie.ch

The values fluctuate to a considerable extent over the years (see the example of capacitors in → Fig. 1). There are various factors responsible for this:

- The composition of the equipment to be processed can vary significantly from recycler to recycler
- Removal techniques vary in practice
- Recording systems are different from operator to operator

The differences between operators' individual annual values (points connected with a dark-green line in → Fig. 1) are substantial. On the other hand, the average over the same ten years (light-green thicker line) varies only slightly. The distribution of the values reported has been analysed and, from this, the most likely value for the ratio of capacitors and batteries in the equipment has been derived. Implausible individual values which are clearly the result of recording errors are excluded from the analysis.

Fig. 1: Ratio of capacitors removed to total devices processed (specific values) by individual recyclers and as an average[2)]

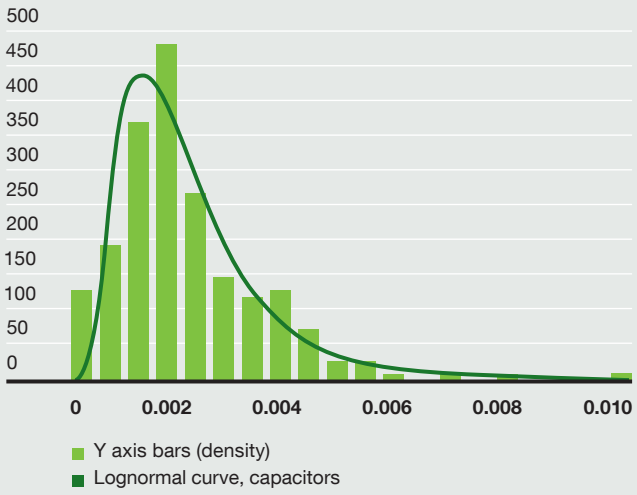


[2)] Refrigeration appliances and lighting fittings are not included among the equipment processed because they contain no capacitors.

Agreement on values

A suitable means of illustrating a distribution is the histogram (see the example of capacitors in →Fig. 2). From the histogram it can be seen that most values lie between 0.001 and 0.002 (light-green bars). However, larger and smaller values also occur. The dark-green line shows the adjusted lognormal distribution. Theoretically, this occurs when many independent values are measured which are always larger than zero. From →Fig. 2 it can be seen that the measured data are a good match to the lognormal distribution.

Fig. 2: Frequency diagram of specific values for capacitors[3] from all recyclers over 10 years (total 217 values)
Density against capacitors removed



[3] The specific value shown is the ratio of capacitors removed to the total quantity of appliances processed (excluding refrigeration appliances and lighting equipment) per year per batch.

Benchmarks and intervention values

The most likely ratios of capacitors and batteries in electrical and electronic equipment can be derived from the statistical analyses. These ratios can be used as a benchmark for the removal of capacitors and batteries. Every recycler should refer to this benchmark whenever he wants to evaluate his performance as far as the removal of batteries and capacitors is concerned. If a recycler clearly falls short of or exceeds this benchmark, a check on the recycler's removal and recording systems would be called for since in all probability there is a problem with the removal process or the data recording. The appropriate intervention values are set out in →Fig. 3. The spread between the upper and lower intervention values takes account of the different composition of the electrical and electronic equipment processed from recycler to recycler and from year to year as well as variations in the quantities of capacitors and batteries in particular equipment.

From which equipment are batteries removed?

Inspection authorities run so-called batch tests at the recyclers independent of the recording of annual materials flows. A batch test is a monitored procedure lasting one day where the input is accurately established and all outputs from the processing are measured. Thus batch tests also provide specific values for the ratio of batteries (or capacitors) in the equipment. Since the batch tests on the processing of large domestic appliances, SENS products (kg) and electronic appliances are undertaken separately, they provide specific values for all three appliance categories. By contrast, the annual materials flow records cannot differentiate as to which

Fig. 3: Benchmark and intervention values for batteries and capacitors

Component	Intervention value	Benchmark
Batteries	0.23 %/0.68 %	0.45 %
Capacitors	0.09 %/0.27 %	0.18 %

appliance categories the batteries come from. As might be expected, the batch tests reveal virtually no batteries in large domestic appliances. There are discrepancies, though, between results based on annual specific values and those from batch tests which indicate the need for further analysis.

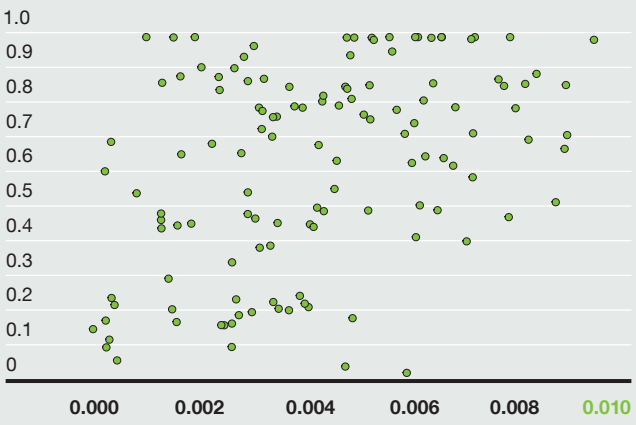
An analysis of the number of batteries removed as recorded in the annual materials flow relative to the proportion of small appliances (SENS products [kg] + SWICO equipment) shows only a small correlation between the two amounts → Fig. 4. Recyclers who rarely process small appliances are bound to have correspondingly low amounts of separate batteries from EE equipment, while recyclers who process large quantities of small appliances are also going to show large quantities of batteries. As it happens, this link to the type of input products is not very marked and other factors in the removal and data-recording processes are more significant.

Conclusion: good existing recording system

All in all, it should be said that the specific values are very useful for checking the removal of pollutants and the recording of material flows at recyclers and, as required, implementing measures for improvement. The recording system for the specific values in Switzerland has been steadily improved over a period of 10 years. Its convincing success has also been influential at European level in that it has been incorporated into the European WEEELABEX standard (see report page 20). With the benchmarks and intervention values mentioned above, recyclers and inspection authorities have access to concrete numerical values on the basis of which the quality of the removal and recording of pollutants can be judged.

Fig. 4: Comparison of annual specific values of batteries removed with the proportion of small appliances in the total input of appliances at recyclers

Proportion of small appliances to all appliances relative to total of batteries removed



Ueli Kasser

Chemist, dipl. chem./lic. phil. nat., at the University of Berne and in postgraduate studies at the ETH (Swiss Federal Institute of Technology) Zurich (INDEL, national diploma on problems in developing countries). After initially freelancing in the areas of radioecology, ecotoxicology and industrial hygiene, he became co-owner of Ecoscience – consultants for applied ecology in Zurich – and project leader in the areas of air hygiene, environmental consulting and ecotoxicology. Today, Ueli Kasser is proprietor of the 'Office for Environmental Chemistry' in Zurich, teacher and auditor for ISO 14001 environmental management systems. From the mid-nineties, Ueli Kasser was a specialist inspector for recycling operations on behalf of SENS, produced the standards and guidelines for inspections, represents SENS in the European Association and is a consultant to the WEEELABEX European standards project.

Getting to grips with mercury

In the environmentally friendly recycling of raw materials, it is essential to be able to extract them free of toxic substances. Mercury in particular presents the various processes in the recycling of lighting equipment with major challenges. A joint study by SENS and the Swiss Light Recycling Foundation provides new information.

Between 2008 and 2010 SENS and SLRS (Swiss Light Recycling Foundation) produced a joint study on the environmental impact of various lighting equipment recycling processes. At the centre of the work, alongside aspects of testing, preparation methods and analysis, is the key question of the distribution of mercury in the output fractions of rod-shaped lighting equipment.

Basis for the environmentally friendly use of raw materials

The study has established that mercury accumulates not only in harmful fractions that are known to be polluted, but also in the aluminium end cap fraction which is recycled. The reasons for this are heavily polluted foreign bodies and adhesions the separation of which is to be achieved by improvements in technical procedures in the future. In other recycling fractions, principally the glass fraction, there are hardly any real problems as far as an environmentally friendly re-use of raw materials is concerned. However, a procedure would have to be classified as unsatisfactory, where, in total, too much mercury was deposited in fractions used as secondary raw materials.

In all, around 80 kg of mercury

Clarifications as to the total mercury yield in the processing of around 800 tonnes per year of rod-shaped lighting equipment showed mathematically around 80 kg of mercury (Hg) in the input, of which around 10 kg were found again in usable fractions, and 20 kg in harmful fractions (fractions which come directly from the input). The remainder of around 50 kg was presumably adsorbed in the activated charcoal filters which, for example, could be checked by measuring the exhaust air from the process. In all, it was established that crucial importance is attached to the efficient extraction of mercury in order to achieve the objective of an ultimately complete recycling of the usable material contained in lighting equipment.

Geri Hug

Following chemistry studies and a dissertation at the Institute of Organic Chemistry at Zurich University Geri Hug became a member of the scientific staff and project leader at Roos+Partner AG in Lucerne. In 1994 he became a partner and, from 1997, also managing director at Roos+Partner AG. Alongside consulting in 15 industry sectors as per EAC Codes, he led environmental audits and produced environmental sustainability reports as per UVPV. Furthermore, Geri Hug produced short reports and risk analyses as per StFV, operational and product-based ecological assessments and validated environmental reports. Geri Hug is an inspector at SENS in the field of electrical and electronic waste management as well as lead auditor for environmental management systems as per ISO14001 at SGS.

Mercury

Mercury (chemical symbol Hg) is most dangerous to human beings when inhaled, but it can also enter the body through the skin and damage the central nervous system. It is also known to have adverse effects on the body's immune system. The main concern is not only the acute and chronic human toxicity of elemental mercury, but also the high toxicity of methyl mercury as regards aquatic organisms. On both grounds it is crucial that every effort is made to prevent or reduce, or even eliminate, mercury from the material life cycle when manufacturing or disposing of products containing mercury.

The mercury contained in fluorescent tubes is mainly present in elemental, liquid form. When used as a light-emitting substance, it circulates as metallic vapour, emitting ultraviolet rays, which are then absorbed by the coating on the inside of the tubes, giving off a white light. Fluorescent tubes contain between approx. 5 and 20 mg of mercury, depending on their date of manufacture.

International links

→ **www.ewasteguide.info**
A collection of information and sources to do with the recycling of electrical and electronic equipment. This knowledge base was set up by the Swiss State Secretariat for the Economy (SECO). Implementation was carried out by the Swiss Material Testing and Research Institute (Empa).

→ **www.weee-forum.org**
The WEEE Forum (Forum for Waste Electrical and Electronic Equipment) is the European association of 41 systems for the collection and recycling of electrical and electronic equipment. Its role is the provision and maintenance of a skills platform for cooperation and the exchange of information on well proven practices.

→ **www.step-initiative.org**
Solving the E-waste Problem (StEP) is an international initiative under the leadership of the United Nations University (UNU), to which major players from the spheres not only of the manufacturing, re-using and recycling of electrical and electronic equipment belong but also from government and international organisations. Three other UN organisations are members of the initiative.

→ **www.basel.int**
The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal of 22 March 1989. also simply known as the Basel Convention. This international environmental agreement arose from the awareness of serious abuses in the disposal of toxic waste in developing countries.

National links

→ **www.sens.ch**
The focus of this independent and non-profit foundation is on the take-back, the recycling and the disposal of electrical and electronic equipment in the areas of small and large domestic, refrigeration, building, gardening, hobby and games equipment.

→ **www.swicorecycling.ch**
SWICO Recycling is a neutral non-profit Commission of the Swiss Industry Association for Suppliers of Information, Communications and Organisation Technology. The focus at SWICO Recycling is on equipment from the areas of IT, entertainment electronics, office, telecommunications and graphics industries such as copiers, printers, televisions sets, MP3 and MP4 players, mobile phones, cameras, etc., as well as measuring and medical technology.

→ **www.slrs.ch**
The Swiss Foundation for the Recycling of Lighting Equipment (SLRS) organizes the across-the-board disposal of lighting equipment and illuminants throughout Switzerland. Amongst other things, the SLRS sphere of activity also covers the training and sensitising of market participants in relation to the recycling of lighting equipment and illuminants as well as providing information for all relevant stakeholders.

→ **www.e-waste.ch**
This website contains an overview of Swiss participants in the recycling of electrical and electronic equipment. Furthermore, this website (only available in English) contains a wealth of information on the recycling of EE equipment. It also covers political decisions and contains a historical summary.

→ **www.swissrecycling.ch**
Swiss Recycling, as an umbrella organisation, promotes the interests of all organisations involved in separate collection and recycling in Switzerland. The ensuing network facilitates the exchange of experiences between members and encourages the development of synergies.

→ **www.empa.ch**
The Swiss Material Testing and Research Institute (Empa) is a Swiss research institute for applied materials science and technology. Its research area covers material handling cycles, the extraction of secondary materials and environmentally friendly recycling.

Authorities and the Confederation

→ **www.bafu.admin.ch**
Under ‘waste’ on its website, the Federal Office for the Environment (BAFU) offers a range of further information and news on the subject of the recycling of electrical and electronic equipment.

Cantons with devolved powers

→ **www.awel.zh.ch**
On the website of the Office for Waste, Water, Energy and Air (AWEL) under ‘Waste, raw materials and contaminated sites’ there is a wealth of information of direct significance for the recycling of electrical and electronic equipment.

→ **www.ag.ch/bvu**
The website of the canton of Aargau’s Department of Building, Transport and Environment, under ‘Environment, nature and countryside’, offers further information on the re-use and recycling of raw materials.

→ **www.umwelt.tg.ch**
On the website of the canton of Thurgau’s Office for the Environment, under ‘Waste’, there is relevant regional information on the recycling of electrical and electronic equipment.

Contact

SENS
Obstgartenstrasse 28
8006 Zurich
Tel. +41 43 255 20 00
Fax +41 43 255 20 01
E-mail info@sens.ch
→ **www.sens.ch**

Technical Control Office SENS
Coordination TK-SENS
Roman Eppenberger
Obstgartenstrasse 28
8006 Zurich
Tel. +41 43 255 20 00
Fax +41 43 255 20 01
E-mail roman.eppenberger@sens.ch

SWICO Recycling
Hardturmstrasse 103
8005 Zurich
Tel. +41 44 446 90 94
Fax +41 44 446 90 91
E-mail info@swicorecycling.ch
→ **www.swicorecycling.ch**

Technical Control Office SWICO Recycling
c/o Empa
Coordination TK SWICO Recycling
Heinz Böni
Technology and society department
Lerchenfeldstrasse 5
9014 St. Gallen
Tel. +41 58 765 78 58
Fax +41 58 765 58 62
E-mail heinz.boeni@empa.ch

Swiss Lighting Recycling Foundation SLRS
Altenbergstrasse 29
P.O. Box 686
3000 Bern 8
Tel. +41 31 313 88 12
Fax +41 43 31 313 88 99
E-mail info@slrs.ch
→ **www.slrs.ch**

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