Swico, SENS & SLRS

Technical Report 2015

FOREWORD

(Not) a quiet year

There are years in which little seems to happen, and yet at the end of the year one realises that an enormous amount has been achieved. The past reporting year can be classified in this category: Outwardly very little has changed, both in the systems themselves and in the regulatory environment, and yet behind the scenes there was much to be done.

In general, we find that we have to use more and more expertise and resources for the execution of projects of overriding importance, which are then lacking in our daily business. We have two strategies to deal with this development: on the one hand, we further strengthen cooperation among the systems including mutual representation on committees and in organisations, or the pooling of human resources; on the other hand, for specific technical issues we do not hesitate to consult external experts who relieve us with their professional reports and specialist services.

An excellent example of both approaches is the joint Technical Commission (TC) of Swico, SENS and SLRS, which controls all environmental aspects of our work and further develops the state of the art. The recycling and auditing expertise of Switzerland come together here. And here, in joint discussions, directions are set, which are accepted and adopted by the management bodies of the systems, but also by our business partners and even by the environmental authorities, generally with no great changes.

In 2014, in addition to dealing with many operational issues, the TC worked intensively on current topics such as the introduction of the CENELEC standard in Switzerland and the implementation of the new ADR regulations as well as providing support to the FOEN for the development of implementation guidelines on the state of technology. The status of these important projects is described in the following pages.

Close cooperation also takes place at the level of the governing bodies. Thus, in conjunction with the FOEN, we shared our ideas on the implementation of the VREG revision. Based on a critical assessment on our part, it appears that the implementation concept has been significantly lightened and structured in such a way that there are considerably fewer disincentives. We are pleased that our technical input was well received and largely incorporated by the Federal Office. Today, we are much more confident than we were one year ago that, even under the new VREG, viable and economically feasible disposal of waste equipment will be possible.

Jean-Marc Hensch	Heidi Luck	Silvia Schaller
Swico	SENS	SLRS

Contents

SENS Foundation, Swico & SLRS: Competent and sustainable

For more than 20 years, the three take-back systems, SENS, Swico and SLRS, have ensured the resource-efficient collection, recycling and proper disposal of electrical and electronic equipment. The growing volume of returns is testament to the success of the work of the three systems.

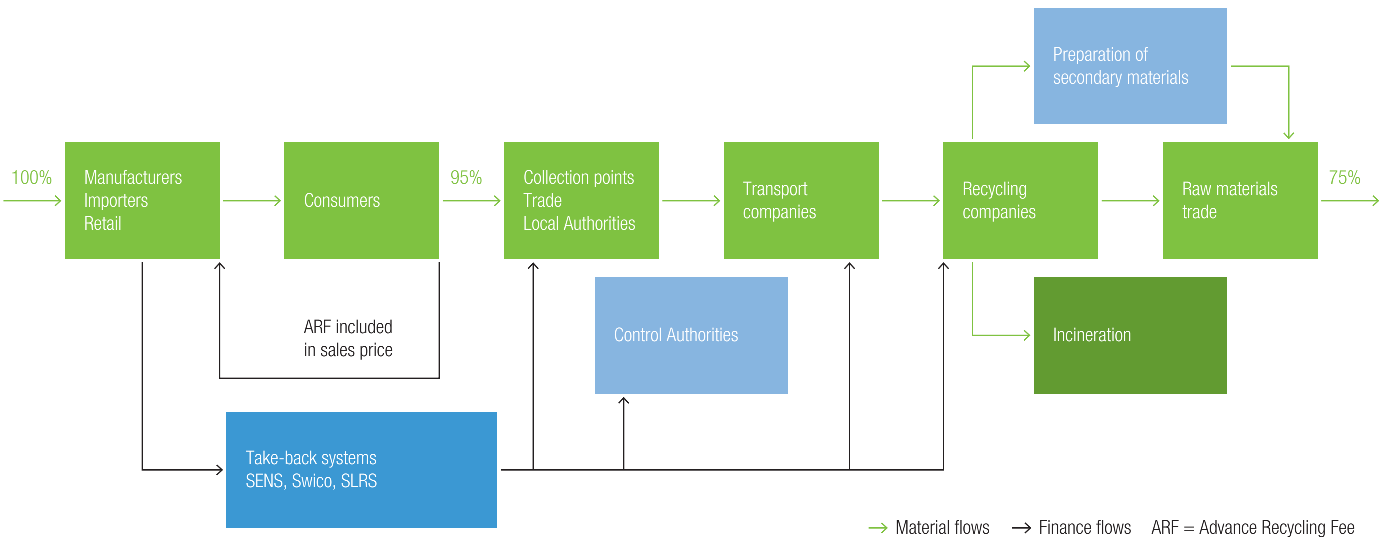
In Switzerland, there are three take-back systems in the area of electrical and electronic equipment. The splitting over three systems is due to historical reasons, because in the early years of institutionalised recycling industry-specific systems were established. The aim of this was to ensure proximity to the respective sectors in order to respond to their specific needs. This also helped to dispel initial reservations against until now voluntary participation in a take-back system. Depending on the type of electrical or electronic device concerned, today either Swico, the SENS Foundation or the Light Recycling Foundation Switzerland (SLRS) is responsible for the take-back.

In 2014, the three systems disposed of around 126,600 metric tons[1] of disused electrical and electronic equipment. Thus Swico, the SENS Foundation and SLRS also contributed significantly to the fact that valuable resources were returned to the economic cycle. Through international networking of the three organisations at the European level - for example, as members of the WEEE Forum (Forum for Waste Electrical and Electronic Equipment) – they also help to set cross-border standards for the recycling of electrical and electronic equipment.

The Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (VREG) obliges dealers, manufacturers and importers to take back free of charge devices that they have in their product range. In order to competitively finance the sustainable and environmentally responsible recycling of electronic and electrical equipment, an advance recycling fee (ARF) is levied on the purchase of such equipment. The ARF is an efficient financing tool which ensures that Swico, the SENS Foundation and SLRS can assume responsibility for the proper handling of equipment in their respective fields and meet the challenges of the future.

[1] This is the amount according to the material flow reports of the recycling companies. This is not equivalent to the amount accounted for in the annual financial statements or annual reports of SENS and Swico Recycling.

Overview of the take-back system



Swico

Swico Recycling is a special fund within the Trade Association for Digital Switzerland, Swico, which deals exclusively with the break-even recycling of waste equipment. The goal of Swico's activity is to recover raw materials and dispose of harmful substances in an environmentally sound manner. Here, Swico's focus is on devices in the fields of information technology, consumer electronics, office equipment, telecommunications, the graphics industry and measurement and medical technology, such as copiers, printers, TVs, MP3 players, mobile phones, cameras, etc.. A close cooperation with Empa, a research and services institution for material sciences and technology development within the ETH domain, makes a major contribution to the fact that Swico is able to enforce high, uniform quality standards for all waste management services throughout Switzerland.

SENS Foundation

The SENS Foundation is an independent, neutral, non-profit foundation and operates outwardly under the brand name SENS eRecycling. Its focus is on the taking back, recycling and disposal of electrical and electronic equipment in the areas of household, fitness, wellness, leisure, toys, pet supplies, photovoltaics and electrical tools. For this purpose, the SENS Foundation works closely with specialised networks in which the parties involved in the recycling of electrical and electronic equipment are represented. In cooperation with its partners, the SENS Foundation is committed to ensuring that the recycling of these devices takes place in accordance with economic and ecological principles.

Light Recycling Foundation Switzerland (SLRS)

Light Recycling Foundation Switzerland (SLRS) bears fundamental system responsibility for lamps and illuminants. The SLRS is concerned with organising the nationwide disposal of lamps and illuminants in the whole of Switzerland. To finance these activities, the SLRS manages a fund for lamps and illuminants, which is provided from the respective ARF. Its activities also include training and raising the awareness of market participants in relation to the recycling of lamps and illuminants, providing information to all stakeholders about the activities of the SLRS. The SLRS maintains a close partnership with the SENS Foundation in all areas. Hence, at the operational level the SENS Foundation as a contractual partner of the SLRS through its take-back and recycling system implements not only collection and transportation, but also recycling, monitoring and reporting in the field of lamps and illuminants..

Heinz Böni / Roman Eppenberger

Material responsibility and lithium batteries

In 2014, the 8 external inspectors performed 31 audits of recycling partners of Swico, SENS and SLRS and 39 audits of manual dismantling plants (contractors of recycling companies). The total expenditure of time including preparation and follow-up is likely be in the range of approximately 100 days. In addition to these long-established control activities, the Technical Commission of Swico, SENS and SLRS also deals with issues that concern either new devices and the possible challenges and risks associated with them or which are important in relation to the technical regulations. In the past year, the material responsibility of the contracted recycling companies and the risks associated with lithium batteries were in the foreground.

The recycling partners were reminded in a letter in late May of a key provision in the technical regulations, which requires them to be responsible for compliance by the (Swiss) dismantling plants with the requirements of the technical regulations and in the work of the (mostly foreign) downstream partners. This means that they must inform themselves of the processing methods that these partners use and how they separate the fractions into those containing harmful substances and those containing recyclable materials.

The aim of this is to prevent the technical regulations, which are controlled and enforced in Switzerland, from being bypassed by foreign partners, which are sometimes subject to less stringent legal requirements and where checks are not carried out with the same intensity as in Switzerland, thereby distorting competition. For this purpose, recyclers must obtain from their partners so-called material flow certificates, which provide information about the procedures followed, the fractions thereby obtained and the customers served. The control experts check this information either at random or by inspection of downstream partners. For critical fractions, in particular, such as plastics, these inspections are carried out regularly, approximately once every 3-5 years.

The topic of lithium batteries in devices that end up in the take-back channel of Swico, SENS and SLRS (see Technical Report 2014) is already a perennial issue. The Technical Commission devoted its annual advanced training event in the autumn to this issue. After a visit to the Kyburz company in Freienstein, which produces electrical postal service tricycles and faces special safety challenges in the use of lithium batteries, a visit was made to Empa in Dübendorf with regard to the fundamental issue of the suitability of lithium as an energy source (Rolf Widmer, Empa), the question of the functionality and composition of such batteries (Donat Adams and Dominik Bachmann, Empa) and their collection and transportation (Reiner Werren, Inobat). The ensuing discussion revealed that the issue is highly topical in the light of various incidents and more stringent ADR regulations and that the subject of lithium batteries in equipment necessarily requires a solution as soon as possible. An article in this Technical Report is devoted specifically to this topic.

Ueli Kasser / Heinz Böni

Formally significant, in substance slight diffferences

Part I of the EN 50625 series on the «Collection, Logistics and Treatment of Waste Electrical and Electronic Equipment (WEEE)» has been in force for one year. Further parts on lighting equipment as well as technical specifications for limit and target values were recently published. It is time to compare the work of the European Standards Organisation with the technical regulations of Swico / SENS, although the entire series has not yet been published. The comparison is all the more contentious because, in the final analysis, the European Standard is attributable to the standard of the Swiss take-back systems[2].

The work of the European Committee for Standardisation (ECS) is progressing with great speed. The main standard EN 50625-1 and the standard EN 50625 2-1 for lamps as one of the four specific standards have already been published. The already published EN 50574:2012 as well as TS 50574 2:2014 for the treatment of household refrigerators and freezers is being revised for the EN 50625 series. Of the total of 7 Technical Specifications (TS), TS 50625-3-1 on the elimination of harmful substances from devices is the most important of those published (see Fig. 1)[3]. The speed with which the CENELEC Commission is drafting and adopting the standards documents is astonishing when one considers that in total more than 50 members represent all the major stakeholders. In addition, all documents are submitted to the national standards organisations for consultation, sometimes twice.

Developed from experience

The origin of the technical regulations (TR) of SENS and Swico in Switzerland dates back to the nineties, when there were no VREG or WEEE directives. At that time, in the context of contracts between recycling companies and SENS / Swico, requirements were established with regard to the treatment of waste equipment. The two systems periodically adjusted the requirements in accordance with the latest findings and legislation, harmonised them in 2009 and issued them as the common technical regulations (see Fig. 2)[4]. The regulations were drafted, adopted and revised as necessary by the joint Technical Commission of Swico, SENS and SLRS, the controlling body for the three systems. The Federal Office for the Environment (FOEN) in April 2012 declared the technical regulations of SENS / Swico as the «state of the art» in accordance with Article 6 of the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (VREG). The technical regulations of the Swiss take-back systems were translated into English in 2009 and served as the first draft of the WEEELABEX project, whose output was used in 2011 as a basis for the CENELEC Commission[5].

Comparison with reservations

It is natural - and of great interest to the systems, the FOEN and the recyclers – to compare the European child with its Swiss mother. However, this comparison is not yet conclusive, because certain details such as the mercury limits for lamp fractions are (still) missing in the CENELEC documents. The comparison of two sets of documents with a completely different structure, different formulations and levels of detail is challenging. The European standards are subject to strictly defined rules. For example, the text must always be normative, i.e. it must contain binding formulations. The word «should» is not permitted. Explanations and informative messages are only possible as notes in small print. When drafting the technical regulations of Swico / SENS, there were no preimposed specifications and no external consultations were required to be performed. The technical regulations are strongly influenced by the many years of background experience of the systems and of the control experts involved in them, who monitor compliance with these regulations.

Figure 1: EN 50625 series – collection, logistics and treatment of Waste Electrical and Electronic Equipment (WEEE)

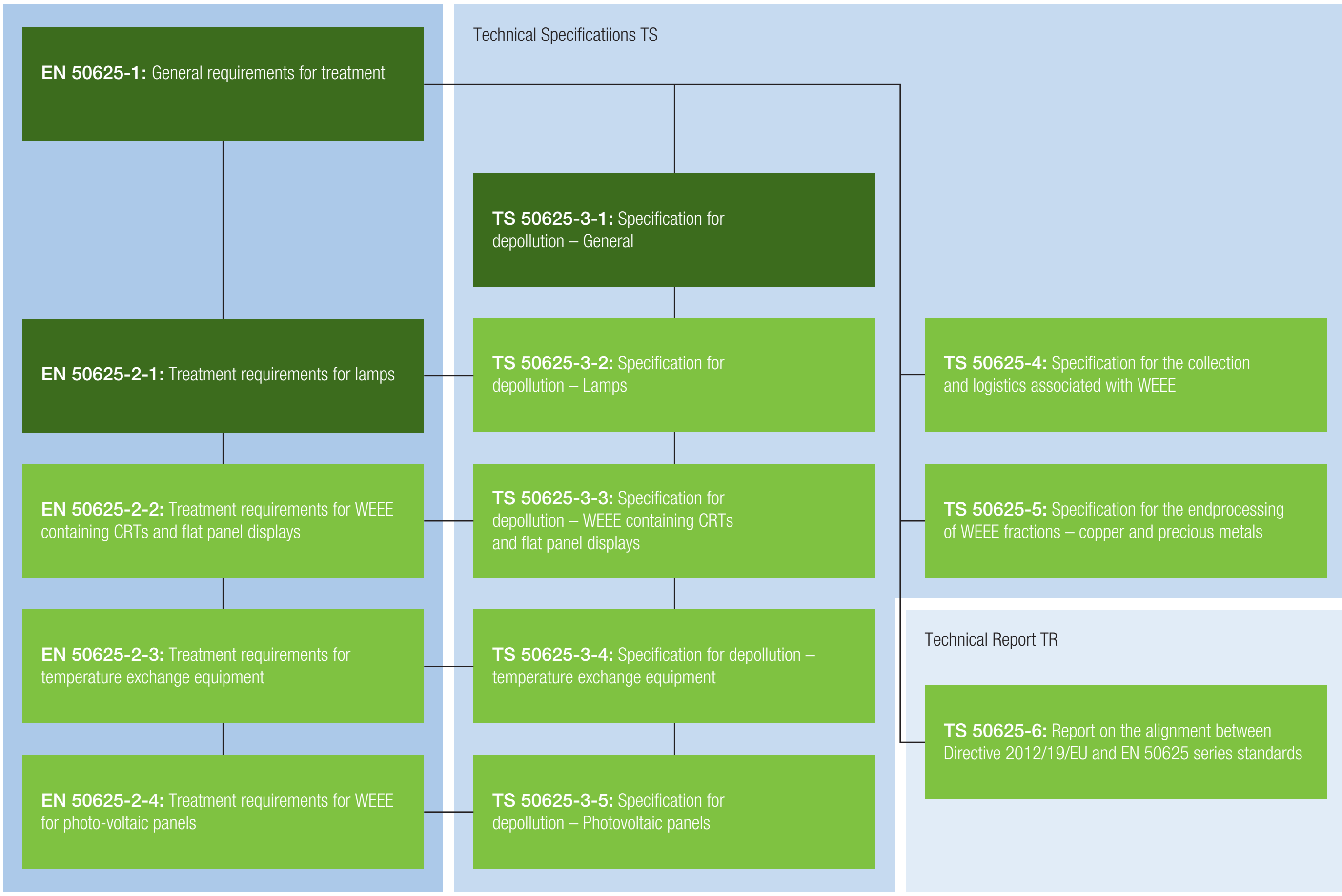
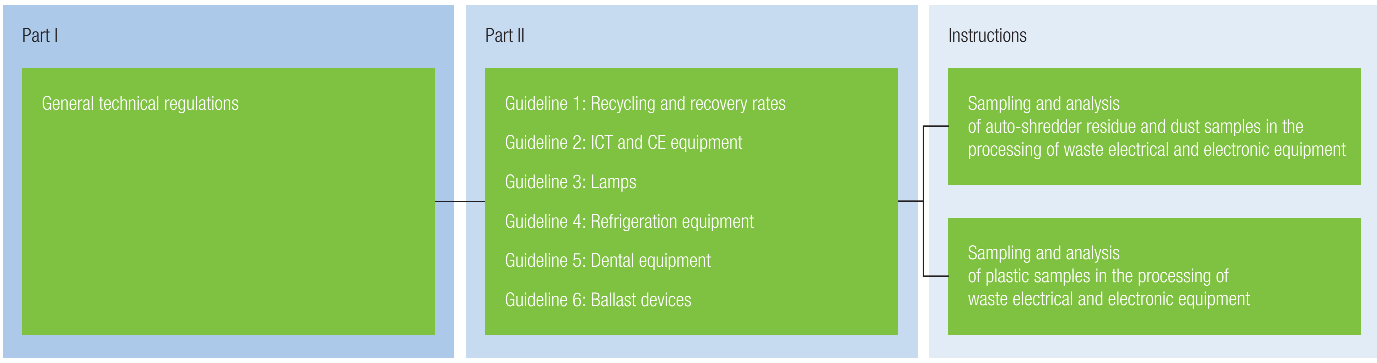


Figure 2: Swico/SENS – Technical regulations for the disposal of waste electrical and electronic equipment



More extensive, more comprehensive and with a clearer structure

The external differences between the standards are summarised in Table 1. The most striking is the volume of documents. While the Swiss technical regulations are composed of slightly more than 50 pages, the corresponding standards series, when complete, will probably comprise about 200 pages. However, the scope of application, which includes photovoltaic panels, requirements on the final processing of fractions and requirements on collection points, is also more comprehensive.

Both standards are aimed exclusively at the operators of systems which process Waste Electrical and Electronic Equipment (WEEE). In addition to the formal aspects, which to a large extent lead to the European standards, there are also differences in content. The European standard contains redundant elements and goes into more detail. This is also due not least to the size of the Commission. Many stakeholders look after their own hobby horses and areas of expertise, which they want to be included in the standard. This often prevents pragmatic and simple solutions. On the other hand, compared to the original Swiss document the European follow-up product has gained in definition and precision.

Table 1: External differences between the Swiss and European standards

Item	EN 50625 series	TR SENS/Swico – CH
Scope of documents	1 Main Standard (40 pages) 4 Part Standards (approx. 70 pages) 7 Technical Specifications (approx. 80 pages)	Part I: General Regulations (16 pages) Part II: 6 Guidelines (29 pages) 2 Instructions (9 pages)
Scope of application	Basically all WEEE old appliance categories from collection to “end-of-waste-status” Explicitly: Lamps, monitors, refrigeration equipment and PV panels Collection points and requirements on the final processing of copper and precious metal fractions	All VREG equipment from receipt to disposal-ready or recyclable fractions Explicitly: Lamps, ICT and CE equipment, refrigeration equipment, dental equipment and ballast devices; no requirements on collection points, PV panels and the final processing of fractions
Addressee	Operators, all operations that collect, sort and process WEEE	Recycling operations (without collection points)
“Philosophy”	More detailed, in part more precise descriptions, requirements partly redundant	Simple and pragmatic

2 see also SENS, Swico & SLRS Technical Report 2014 “First European e-waste standard is ratified” by Ueli Kasser.

3 EN 50625-1, EN-50625-2-1 and TS 50625-3-1 can be ordered at:
https://www.electrosuisse.ch/de/meta/shop/normen.html

4 SENS / Swico Recycling; Technical Regulations for the Disposal of Waste Electrical and Electronic Equipment PART I GENERAL TECHNICAL REGULATIONS, PART II GUIDELINES, 8.12.09/supplemented 02.11.2011.

5 see footnote 2

6 The objective is contained in the “Waste Framework Directive” of the EU. This allows lengthy transitional periods for EU Members. In principle, no statutory requirements are incorporated in the standards.

Table 2: The most important differences between the Swiss and European Standards (as identifiable from the current versions)

Item	EN 50625 series	TR SENS/Swico – CH
System design, safety and protective measures	Duty to perform a risk analysis in order to derive from it the layout of the system and the safety and protective measures	No explicit requirement for a risk analysis
Processing principles	Mixed processing with other waste is permitted	Separate processing of WEEE mandatory (exceptions require approval)
WEEE maximum storage quantities	12 months processing capacity, lamps 6 months	20 % of average annual turnover
Weather protection for WEEE storage areas	Explicitly for lamps, refrigeration equipment and VDUs	Explicitly for lamps, basically for all WEEE (exceptions: evidence of wastewater discharge, devices from which harmful substances were removed)
Monitoring of the subsequent treatment chain	Precise requirements differentiated by type of fractions Up to "end-of-waste" status	Material flow certificate, however relatively little difference in detail
Limits of harmful substances in auto-shredder residue	No limit value for copper Cadmium 100 mg/kg PCB 50 mg/kg	Copper 10,000 mg/kg Cadmium 100 mg/kg PCB 50 mg/kg
Mercury limit values in lamp fractions	Probably significantly higher values (10 / 100 ppm)	Glass 5 mg /kg Metal and others 10 mg /kg
Disposal of incinerable waste	Duty of incineration is formulated as an objective in the EU, not however implemented in all countries[6]	General duty of incineration

Core elements almost identical

Despite the differences in formal and structural terms, the substance of the standards is very similar. The removal of harmful substances from the equipment and the recycling and recovery of materials are key elements of all WEEE processing technologies. Both elements are practically identical in the standards, i.e. the Swiss approach was adopted by the CENELEC Commission with no fundamental changes, but with clarifications. The target and limit values for the removal of harmful substances and for the recycling and recovery rates are determined in a batch test every two years for each device category. The batch must represent «daily business» in relation to input and technology; the minimum input quantities are formulated somewhat more precisely in the EN.

Differences without major consequences

The recycling and recovery rates to be achieved are identical, the Swiss targets for the removal of batteries and capacitors from certain categories of equipment were accepted (country-specific) and the European values (default) are no less stringent. Only in relation to the limit values for harmful substances in auto-shredder residue did the CENELEC Commission decide against the limit value for copper (see Table 2). The mercury limits of lamp fractions will probably also turn out to be higher than in Switzerland. Other differences not affecting the fundamental nature concern the duty to perform a risk analysis as a basis for operational measures, the separate processing of WEEE and the requirements for the storage of WEEE. An important principle of waste management was also retained in the EN standard and indeed made more stringent compared to the Swiss variant: The duty of the primary handler to monitor the subsequent process chain.

The next challenges – implementation

For Swiss recyclers the EN standard is of little consequence compared to previous practice. There will also be little change with regard to the inspection of operations. The initial inspection will probably turn out to be somewhat more extensive, while the subsequent inspections are likely to remain the same in terms of their duration. This is quite different in much of Europe, especially in those countries where the removal of harmful substances is considered optional and the determination of the recycling and recovery rates was left entirely at the discretion of the recycler. The challenge remains, therefore, for the European standard to be applied throughout the whole of Europe and controlled according to the same criteria.

Esther Thiébaud

Stabilisation of e-waste quantities at a high level

As in the previous year, the processed quantity of electrical and electronic devices decreased by 1% in weight. While in 2013 it was consumer electronics products that took a downward turn, the decline in 2014 relates to household appliances, which makes it almost impossible to extrapolate trends. Not only do collecting activities and processing quality influence the total quantity, but also other factors such as technological developments, consumer preferences, product cycles and usage patterns. In any case, the quantities taken back seem to have reached a plateau, whereby significant increases hardly seem possible.

In 2014, Swico and SENS recyclers processed around 126,600 metric tons of electrical and electronic devices. As in 2013, the quantity decreased by 1% compared to the previous year (Table 1 and Figure 1). The processing of large household appliances and electronic equipment each fell by 1,200 metric tons, or by 4% and 2% respectively. With regard to non-VREG devices, which are not listed in the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (VREG), the processed quantity also declined by about 1,000 tons. By contrast, small household appliances continue to register an increase. If one looks back over the last six years, the processed quantities of large electrical appliances, refrigerators and lamps are relatively constant. The processed quantity of small electrical appliances, on the other hand, showed an average increase of 10%. The recycling of electronic equipment increased steadily until 2012. Since then the take-back of CRT monitors has decreased, which in turn affects the total volume of electronic equipment. However, because the sales figures of most device categories continue to rise while the size of the individual devices is decreasing, only the coming years will show how the total processed quantity continues to evolve.

High demands on the removal of harmful substances

Fractions of both recyclable materials and harmful substances are obtained from electrical and electronic appliances as a result of manual and machine processing (Figure 2). The major recyclable fractions are metals with 56%, plastics with 13% and metal-plastic mixtures with 11%. The glass from CRT processing still amounts to nearly 7%. Of the total quantity, particularly valuable PCBs and harmful substances account for only 1.5% and 1%, respectively. Nevertheless, it often pays to manually remove the most valuable materials in advance for mechanical processing. The removal of harmful substances also occurs largely manually. Thus, for example, capacitors are removed from large household appliances, batteries are taken out of electronic devices and backlighting is removed from flat panel displays, scanners and copiers. Here, the removal and handling of harmful substances must be constantly adapted in line with changing technologies and the latest developments. Nevertheless, the operators must be able

Total processed electrical and electronic equipment in Switzerland in metric tons from material flow records

Year	Large household appliances	Refrigerators, freezers and air conditioning equipment	Small household appliances	Electronic equipment	Lamps	Non-VREG equipment	Total tons/year
2009	30,400	15,300	14,900	47,300	1,100	1,200	110,200
2010	30,700	15,900	15,400	50,700	1,130	3,500	117,400
2011	27,800	16,800	16,300	51,300	1,110	5,200	118,500
2012	30,300	17,500	18,800	55,500	960	6,000	129,100
2013	30,600	16,700	22,300	53,200	1,100	4,000	127,900
2014	29,400	17,200	23,900	52,000	1,100	3,000	126,600
Change compared to previous year	**–4%**	**3%**	**7%**	**–2%**	**0%**	**–25%**	**–1%**

Figure 1: Development of processed equipment quantities in Switzerland in tons

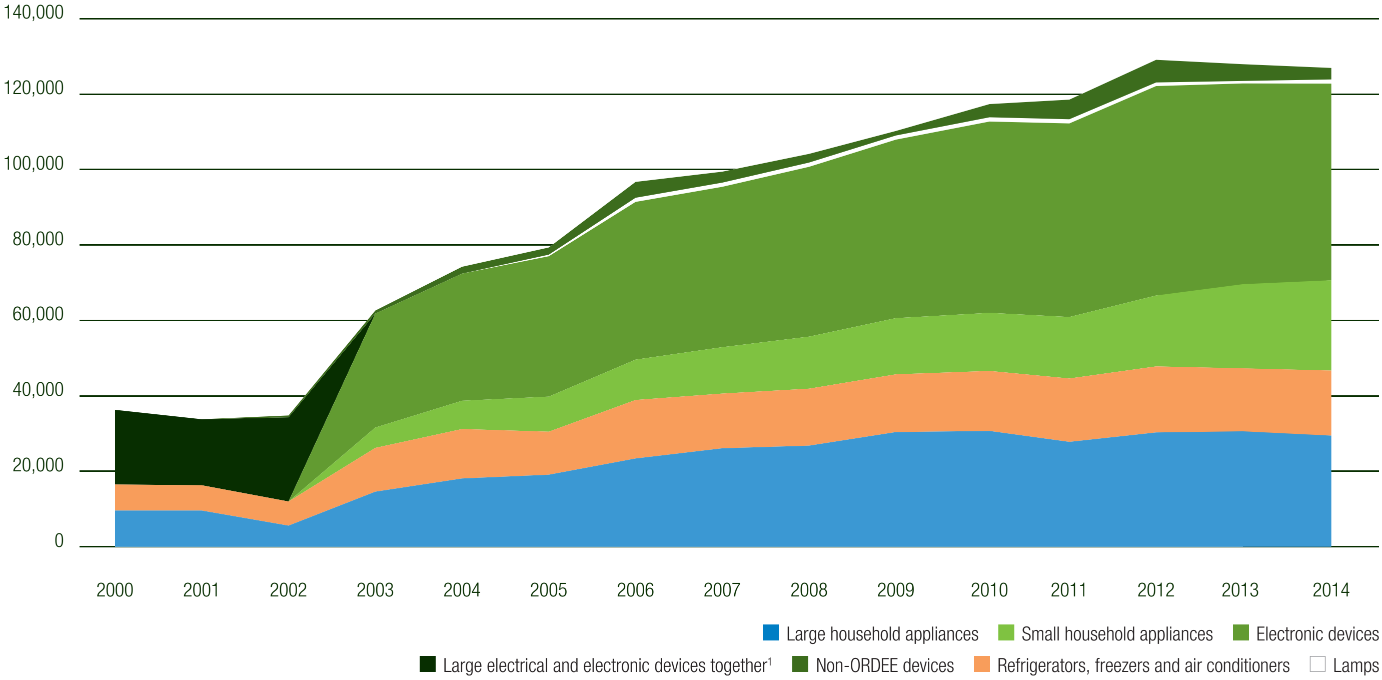
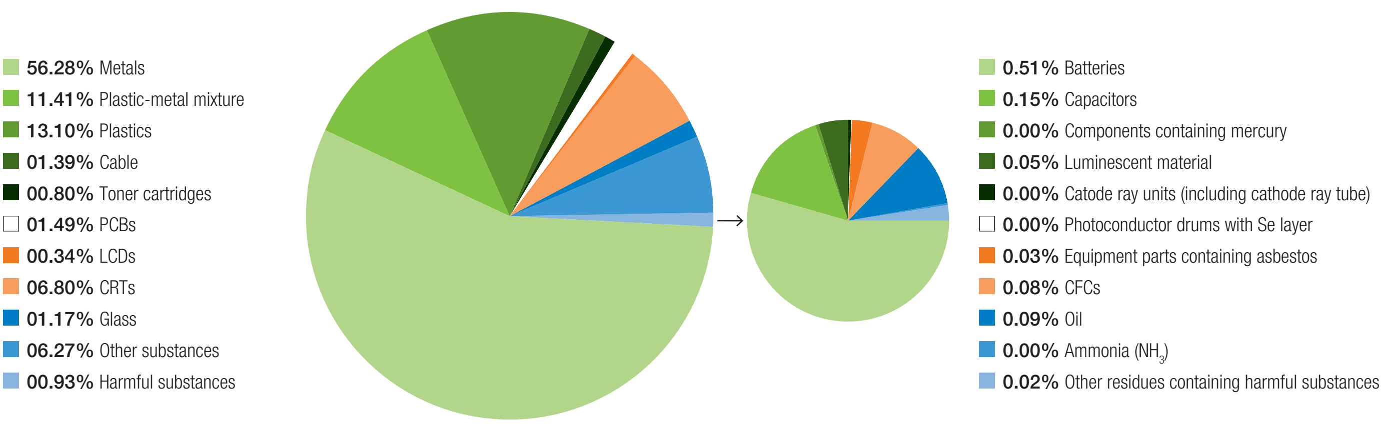


Figure 2: Composition of the produced fractions in % in 2014



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

Table 2: Collected Swico quantities and composition by equipment type

	Quantity[9]	Ø-weight	Metals	Plastics	Metal-plastic mixtures	Cable	Glass and / or LCD modules	PCBs	Harmful sub-stances	Others[10]	Total	increase/decrease compared to 2013
PC monitors, CRT	138,000	17 kg	340 t	461 t	220 t	60 t	1,013 t	212 t	0.1 t	11 t	2,316 t	–25 %
PC monitors, LCD	491,000	6.3 kg	1,329 t	744 t		12 t	783 t	216 t	10.1 t	14 t	3,108 t	16 %
PCs / servers	415,000	13 kg	4,350 t	304 t	14 t	162 t		441 t	17 t		5,288 t	7.5 %
Laptops	395,000	3.1 kg	374 t	348 t	126 t	6.3 t	109 t	179 t	85 t	5.1 t	1,232 t	1.1 %
Printers	499,000	10 kg	1,700 t	2,580 t	295 t	26 t	33 t	84 t	1.5 t	78 t	4,798 t	–2.6 %
Large copiers / large devices	44,000	169 kg	4,011 t	245 t	2,681 t	134 t	4.4 t	54 t	60 t	179 t	7,368 t	7 %
IT, mixed[7]	472,000	8.3 kg	2,138 t	126 t	1,442 t	72 t	1.7 t	28 t	32 t	94 t	3,932 t	6 %
CRT TVs	467,000	28 kg	1,292 t	2,681 t	436 t	46 t	8,478 t	160 t	13 t	7.1 t	13,112 t	5.2 %
LCD TVs	156,000	16 kg	1,018 t	366 t		49 t	634 t	301 t	23 t	85 t	2,476 t	14 %
CE, mixed[8]	2,662,000	4.4 kg	6,379 t	375 t	4,302 t	214 t	5.1 t	82 t	95 t	281 t	11,733 t	17 %
Phones, mobile	685,000	0.16 kg	18 t	39 t			5.7 t	25 t	22 t		110 t	16 %
Phones, other	1,533,000	1.9 kg	1,583 t	93 t	1,068 t	53 t	1.3 t	20 t	24 t	70 t	2,912 t	1 %
Photo / video	279,000	0.6 kg	91 t	5.3 t	61 t	3.0 t	0.1 t	1.2 t	1.3 t	4.0 t	167 t	2.4 %
Dental											65 t	–7.1 %
Total in tons			**24,622 t**	**8,367 t**	**10,644 t**	**837 t**	**11,067 t**	**1,804 t**	**383 t**	**829 t**	**58,617 t**[11]	**6 %**
Total in percent			**42%**	**14%**	**18%**	**1.4%**	**19%**	**3.1%**	**0.7%**	**1.4%**	**100%**	

to accept, break down and dispose of devices of all generations, including their respective harmful substances, in an environmentally sound manner, which places great demands on the work of the recyclers and requires advanced quality assurance systems.

Unchanged recycling rate

The resulting recyclable fractions are materially or thermally recycled. Metals are recovered in large, mostly European smelters. Around half of metal-plastic mixtures go for further treatment, in which they are separated into solely metal and plastic fractions, the other half is thermally recycled in incineration systems. In 2014, approximately 75 % of plastics were materially recycled. Glass fractions (screen glass, flat glass and recycled glass from bulbs) and cable, circuit boards and batteries are processed further. Overall this again leads to a material recycling rate of 75 %.

Take-back and composition of electronic equipment

Based on market basket analysis and targeted processing trials of certain product groups, Swico Recycling carries out a detailed examination of the take-back quantities of electronic equipment and their composition (Table 2). In 2014, Swico Recycling took back 58,617 metric tons[11] of electronic equipment, 6 % more than in the previous year.

Compared to last year, the quantity of flat screens taken back increased by 16 % (monitors) and 14 % (TV sets). The taking back of mobile phones and smart phones also increased by 16 %. The taking back of CRT computer monitors continued to decline sharply (-25 %). However, the taking back of CRT televisions again increased slightly, which can be explained by the Football World Cup in 2014 and the TV sales associated with it.

The composition of the individual device categories is determined by means of processing trials, which are carried out at the Swico recyclers and accompanied by Empa. Here, a predetermined amount of equipment is collected and the fractions resulting from processing are weighed and documented.

[7] IT equipment, mixed, excluding monitors, PCs / servers, laptops, printers, large copiers / large appliances.

[8] Consumer electronics, mixed, excluding TVs.

[9] Extrapolation.

[10] Packaging and other waste, toner cartridges.

[11] The figure is greater than the 52,000 metric tons of electronic equipment in Table 1, because this also contains equipment which the A-signatories disposed of under direct agreements

Geri Hug / Niklaus Renner

Recovery and destruction of refrigerants and propellants

The trend observed for some time in refrigerator recycling, away from ozone-depleting chlorofluorocarbons (VFC) and towards devices operated by hydrocarbons (VHC) either as refrigerants or propellants, continued in line with expectations also in the last year. Thus in 2014, of the total of 350,000 appliances (17,300 metric tons) taken back by the four recycling companies Kühlteg AG, RUAG Environment AG, Oeko-Service Schweiz AG and Solenthaler Recycling AG, already 53 % had VHC-based compressors and 60 % were of the VHC-foamed PU insulation type.

The atmosphere is grateful

In refrigerator recycling, the refrigerants and propellants contained in the old equipment are not released, but destroyed in a controlled manner. Through high temperature combustion of the gases, on the one hand the atmosphere is protected against substances damaging to the ozone layer, on the other hand the greenhouse effect is counteracted: In the current survey year, the amount of greenhouse gas saved through recovery and subsequent combustion is about 440,000 metric tons of CO_2 equivalents. This amount of CO_2 is exhausted from 75,000 passenger cars, each driving once around the globe.

VHCs have also overtaken VFCs in compressors

Since as early as the year 2000, with regard to the ratio of VFCs (volatile fluorocarbons) to VHCs (volatile hydrocarbons) in foamed appliance housings, a clear increase has been recorded in favour of VHC insulation foam. Here, the «overtaking manoeuvre» took place during survey year 2012; currently the insulation in 60 % of the refrigerators taken back for recycling is of VHC-foamed polyurethane (PU).

Since 2003, a similar trend has developed with regard to VFC and VHC-operated compressors. The two types were on a par for the first time in survey year 2013, and the trend has clearly continued: thus, in 2014, 53 % of the appliances recycled in step 1 were equipped with VHC compressors (+ 4 %). Hence the increase to two-thirds of all devices predicted in last year's Technical Report is running a little off target. The delayed increase for VHC-driven compressors compared to the developments in VHC insulation foams is due to the temporarily increased use of ozone-harmless, yet still greenhouse gas emitting R-134a, which is also categorised as VFC.

Absorber systems containing ammonia still account for around 4 % of all equipment. See. Fig. 1.

Lower recovery quantities as a reflection of the equipment mix

The reduced input of VFC devices both in step 1 (recovery of refrigerants from compressors) and in step 2 (recovery of propellants from insulation foam) is consistently observed in the output. The very much lower VHC filling weights and VHC concentrations in the insulation in conjunction with the lower specific weight of isobutane and cyclopentane compared to conventional VFC also have an effect on the quantities to be recovered.

Figure 1: Development of the device types treated in step 1 (compressors containing VFC and VHC) and step 2 (PU insulation foam containing VFC and VHC)

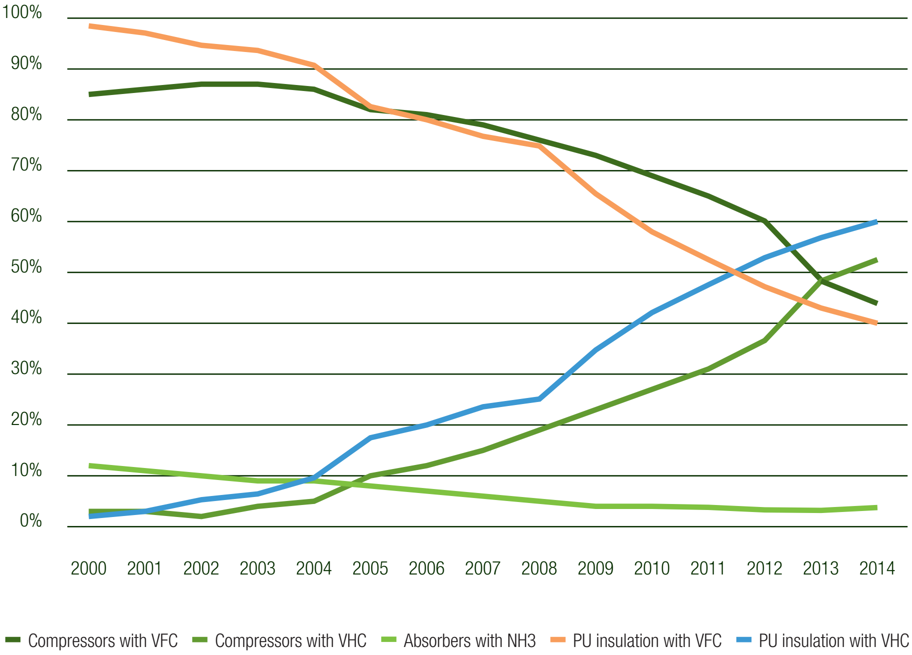
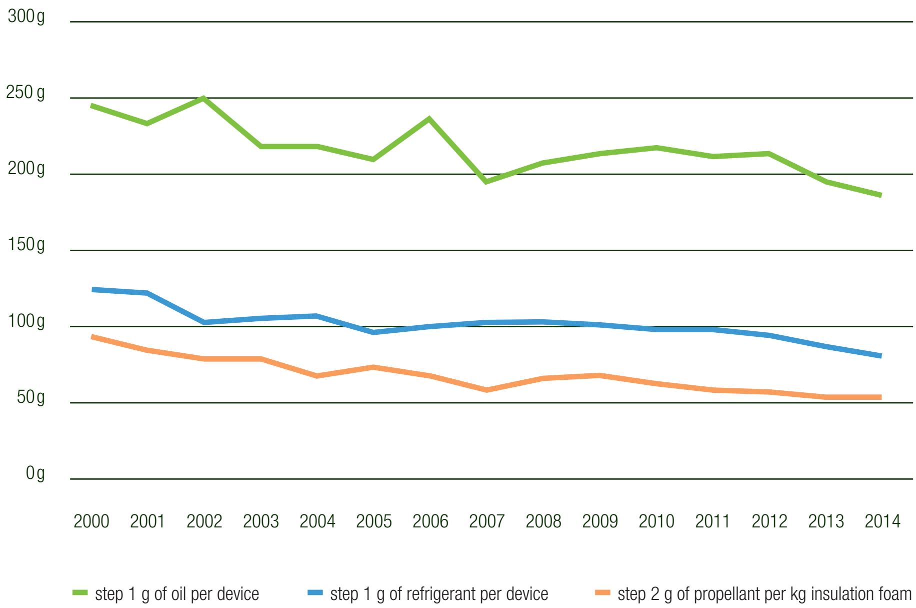


Figure 2: Development of recovery quantities in step 1 (grams of refrigerant and oil per device) and step 2 (grams of propellant per kilogram of foam insulation)



Whereas in 2013 88 g of refrigerant was recovered from each compressor in step 1, in 2014 this figure was 81 g (-8 %), while the quantity of oil decreased from 195 g to currently stand at 186 g (-5 %). The latter figure indicates that the filled in quantity in VHC compressors is lower for both refrigerant and oil.

In step 2, around the turn of the millennium quantities of more than 80 g per kilogram of PU were recovered. This figure then fell continuously (short-term increases in recovered quantities in 2005 and 2009 are attributable to the commissioning of new system components with higher performance). In 2012 the average figure was already down to 58 g and in 2013 lied at 54 g. In the current survey year, this figure is virtually unchanged at 55 g (see Fig. 2). The data situation is consistent with a moderate increase in VHC housing quantities and a small decrease in the specific weight of the propellant mixture (assumption 85 g VFC respectively 38 g VHC per kilogram of PU foam, according to own analysis and manufacturers' data).

On the assumption that end-of-life VFC devices will one day entirely disappear from recycling market, a further reduction in recovery quantities can be expected in the future. Some years will pass before the last VFC device is treated by the Swiss recyclers, which meet high quality standards. Until then, the mixed processing of VFC and VHC devices remains state of the art.

Planned implementation of the requirements of the CENELEC standard

In the near future, the CENELEC standard EN 50625-2-3[12] for the recycling of refrigerators will also be applied in Switzerland and will supersede the previously valid technical regulation issued by SENS. The new regulatory framework favours the continued joint processing of VFC and VHC devices, which from the perspective of SENS also most equitably meets the requirement for an ecologically advanced solution. If recyclers were to seek separate processing of VHC devices, however, the requirements under the CENELEC standard would be extremely high: the VHC would have to be recovered separately from the insulating foam in any case; the recovery quantity would also have to be determined. For each VHC device, «VFC-free» certification would have to be provided using an appropriate method. In addition, it would be necessary to prove that no VFC is emitted to the exhaust air stream, which requires the procurement of accurate measuring instruments.

[12] EN 50625-2-3: Collection, logistics & treatment requirements for WEEE – Part 2-3: Treatment requirements for temperature exchange equipment

Rolf Widmer

Lithium batteries in waste electrical and electronic equipment

The revised «European Convention concerning the International Carriage of Dangerous Goods by Road» (ADR) has been in force since January. It demands particular caution when handling batteries that contain lithium. This gives rise to a number of requirements on the collection and transportation of waste electrical and electronic equipment containing lithium batteries.

In the 2014 Technical Report, the article «Lithium-ion batteries and their disposal» reported on the construction and operation of Li-ion batteries and the safety regulations arising therefrom:

- Prevention of internal and external short circuits
- Immediate professional disposal of damaged products
- Compliance with all requirements of the respective manufacturers and safety data sheets

To prevent fires due to lithium-ion batteries in general, waste electrical and electronic equipment must be handled with greater caution. This means:

- [Low] mechanical stress on the equipment during collection
- [Gentle] unloading of collection containers …
- Packaging of batteries according to ADR regulations

The last requirement was the opportunity to check the legal compliance of existing practice in Switzerland regarding the implementation of the ADR 2015. Swico, SENS and Inobat set up a working group «LIB in WEEE» (lithium batteries in waste electrical and electronic equipment) for this purpose. Its task was to examine the impact of the revised ADR on the Swiss take-back systems and submit conclusions to management. The working group, led by Empa, was composed of representatives of the three systems and representatives of recycling companies and worked closely with ASTRA on this issue. Intensive debates are currently under way worldwide, especially in the EU, regarding how WEEE containing lithium should be treated in everyday operation. The working group is involved in these debates. The expertise of Swiss TS Technical Services AG was called upon as a basis for this. The work is expected to be completed by the end of March. Hence the status reported here (mid March) does not necessarily represent the final version.

The latest ADR version is not the first to classify LIBs as potentially dangerous objects, however their treatment has now been simplified and streamlined. Lithium batteries are still allocated to Category 9 «Miscellaneous dangerous substances and articles» and Packing Group II «Substances presenting medium danger».

In the ADR, differentiation is made between lithium cells (containing Li-metal or Li-ions), lithium batteries made up of several cells, and equipment which, summarily, contains LIBs. Primary lithium cells (non-rechargeable) contain exclusively metallic or alloyed lithium (e.g. button cells). Secondary, rechargeable lithium cells operate at present only with Li-ions in order to prevent a violent reaction of elemental lithium, in the event of a perforation of the cell envelope, due to the penetration of oxygen from water or air. The decisive threshold for the dangerous goods provisions of the ADR is the mass of lithium contained in primary cells or the nominal storable energy in secondary cells, i.e. a threshold measured in grams or in watt-hours. Further differentiation is made regarding whether LIBs are in loose form or installed in equipment and whether they are still intact or damaged / defective.

Legal principles

The parties involved in the dangerous goods process (senders, packers, loaders, carriers, unloaders and receivers) are personally liable for compliance with the duties assigned in ADR. This particularly applies to collection points, which according to the regulations are responsible for correct classification, packing and labelling and the issuing of any required transport documents. The role of system operators under the ADR is to support the parties in maintaining the legal conformity of all dangerous goods processes.

In accordance with the currently applicable dangerous goods provisions of the ADR, WEEE that contains LIB is classified as follows:

- UN 3481 LITHIUM-ION BATTERIES CONTAINED IN EQUIPMENT
- UN 3091 LITHIUM-METAL BATTERIES CONTAINED IN EQUIPMENT
- Partially exempt from the dangerous goods regulations under certain circumstances

Loose LIBs, i.e. not contained in WEEE, are classified under UN 3480 LITHIUM-ION BATTERIES and UN 3090 LITHIUM-METAL BATTERIES.

The associated special provisions and packing requirements are SP 188, 230, 310, 348, 360, **376**, **377**, **636** (Chapter 3.3 ADR) and P903, **908**, **909**, LP 903, 904; those relevant to lithium-containing WEEE are shown in bold.

The following classification table (according to ASTRA) results for not damaged / defective LIBs:

Li-metal or Li-ion cells | batteries, loose or built-in, for disposal or recycling

SP 636 exempted (no ADR transport, no DGSA) if:
- LIBs (including defective) ≤500g and Li-mass ≤1g|2g / Energy ≤ 20Wh|100Wh
- QA for LIB exemption, exemption limit 333 kg per transport
- P909 excluding additional items 1+2

"Loose"

P 909 (2):
- Strong outer packing (gross ≤30 kg) with electrically isolating lining for metal packing

Additional regulations Item 3:
- In outer packing enclosed in padding (securing, insulating)

"Built-in"

P 909 (3):
- Resistant outer packing
- Given an equivalent protection large equipment may be transported unpacked or on pallets

Marking:
- LITHIUM BATTERIES FOR DISPOSAL
- LITHIUM BATTERIES FOR RECYCLING

SP 377:
- No defective LIBs
- Exemption limit 333 kg per transport

"Loose"

P 909 (1):
- Drums, boxes and canisters PGII, with electrically isolating lining for metal packing

Additional regulations Item 1+2+3:
- Short-circuit / thermal protection, insulated padding
- In outer packing enclosed in padding (securing, insulating)

"Built-in"

P 909 (3):
- Resistant outer packing
- Given an equivalent protection large equipment may be transported unpacked or on pallets

P 909 (4):
- LIB ≥12 kg with robust housing in strong outer packingg

Marking:
- LITHIUM BATTERIES FOR DISPOSAL
- LITHIUM BATTERIES FOR RECYCLING

and
- Danger labels
- UN no.
- Transport document

For damaged / defective lithium cells and lithium batteries the special provision SP 376[13] and packing requirements P 908[14] or LP 904[15] generally apply. The marking DAMAGED / DEFECTIVE LITHIUM-ION batteries and / or DAMAGED / DEFECTIVE LITHIUM-METAL BATTERIES and the corresponding danger labels, UN numbers and transport documents are mandatory.

These legal requirements render the following inadmissible in relation to the collection and transportation of WEEE containing lithium:

- The transportation of LIB containing WEEE in bulk in containers is not allowed because for both UN numbers (UN 3091 and UN 3481) no provision is made for carriage in bulk and this is therefore not permitted.
- The compacting and tipping of WEEE is not allowed due to possible damage to their housing and the associated potential for damage to the LIBs.

By contrast, there are various legally compliant options for packing and transportation:

Transport in accordance with special provision 636

If the WEEE for disposal contains only LIBs with an individual mass of less than 500 g or such batteries contain less than 1 g | 2g lithium or 20 Wh | 100 Wh per cell | battery,[16] they are exempted if the following conditions are met:

- Application of packing requirement P909 (see next section)
- Application of a quality management system (QS), which ensures that the total mass of LIBs per transport unit does not exceed 333 kg.
- Marking of the packaging with the text «Lithium batteries for disposal» or «Lithium batteries for recycling»

Advantages: It is not necessary to use a vehicle that is subject to labelling and thus it is not an ADR transport. Also, the appointment of a dangerous goods safety advisor (DGSA) no longer applies. Since this concerns 'other waste subject to control', an accompanying VeVa (ordinance on the movement of waste) certificate is not required. It is recommended to enter the text "Exempted under SV 636" on the delivery note.

Disadvantages: For the practical application of this special provision it would be necessary to create an equipment catalogue as a decision aid for the collection points. The latter, firstly, would have to sort WEEE by LIB content and introduce a quality assurance system which guarantees compliance with the maximum LIB mass of 333 kg per transport unit. The calculated total amount can be used for this purpose, as the following rough calculation shows: In a full trailer with 32 spaces and 250 kg per pallet the mass of WEEE is not more than 8,000 kg. The exemption amount of 333 kg would then correspond to a LIB mass percentage of not more than 4 %. If this were generally respected in today's WEEE mix, this could be declared as given, and an elaborate quality assurance process would no longer be required. For this to happen, however, the market basket analysis of the system operators

Figure 1: Waste electrical and electronic equipment that was tipped from a great height out of collection boxes into a transport container. It is clear to see that waste electrical and electronic equipment splits open and LIB's can be ejected and damaged in the process.

Figure 2: SBB wooden pallets with wooden boxes at a Swico collection point. In order to prevent damage to waste electrical and electronic equipment, the WEEE must not protrude beyond the maximum three stacked boxes.

would have to demonstrate, for example, that this 4 % ceiling can be observed.

Transport in accordance with special provision 377

If the WEEE for disposal does not contain damaged / defective LIBs, it can be transported under P909 provided that the following is observed:

- Unpacked or on pallets with pallet frame without cover, plastic pallets, pallet cages lined with plastic sheeting / big bags. Here it must be ensured that no loaded material overhangs the pallet frame or falls through the pallet. The number of stacked pallet frames must be such as to ensure that the housings of the lowermost electrical appliances are not crushed.
- Or the use of strong outer packing[17] of a suitable solid material, where the packing does not have to be type approved.

Furthermore, it must be noted that

- The batteries must be adequately protected by the equipment (no broken housings)
- Excessive movement of the loaded material must be prevented (load security)
- The pallet / packing must be marked with the text "Lithium batteries for disposal" or "Lithium batteries for recycling" and the danger label no. 9 as well as the UN number (s) UN 3091 / UN 3481[18] pursuant to ADR.

Advantages: No overburdening of collection points due to QMS and sorting tasks.

Disadvantages: If the exceeding of the exemption limit of 333 kg can not generally be guaranteed, transportation must take place in a vehicle subject to mandatory labelling (ADR transport above the exemption limit). In this case, a DGSA must be appointed. A transport document for UN 3091 and UN 3481 must be issued in all cases.

Transport in accordance with special provision 376

LIBs that were found to be damaged or defective must be packed and transported in accordance with SP 376 and packing requirement P 908. However, the integrity of LIBs in an intact, unopened electrical equipment can hardly be established. Therefore, implementation will hardly be possible in daily practice. For this reason, tests (e.g. random sampling of the market basket analysis of the system operators) should establish the condition of built-in LIB's, in order to estimate possible event risks.

Preliminary conclusions

In practice, this legally compliant classification means a change in the collection of WEEE containing lithium, for example in pallet frames, as is already the case today for monitors. By using much smaller packing units, both the drop height and the pressure on the housings are significantly reduced. Through this measure, the lithium batteries remain adequately protected by the housings and the risk of a smouldering or full fire can be significantly reduced.

The general public is still not sufficiently aware of the potential hazards caused by lithium batteries. The fact that most of us constantly use mobile devices with lithium batteries and incidents in everyday life are extremely rare, on the one hand shows how safe this technology is in use; on the other hand it sometimes leads to careless handling. Particularly in the disposal of this equipment, lithium batteries can be treated "outside their specifications" and then show what they are: power generators with great energy and power density that can easily ignite anything flammable. We must learn (as we had to with spray cans for example) that batteries have to be handled carefully at all times, particularly during disposal.

[13] SP 376: Found defective, observe applicable SP, in case of dangerous reaction observe transport conditions of authority.
[14] P 908: Drums, boxes, canisters VG II; individually packed in inner packing, if ≥ 30 kg then only 1 cell / battery per outer packing; inner packing with thermal protection, possibly ventilation and vibration protection; protection against short-circuit)
[15] LP 904: Large packing VG II, individually in inner packing
[16] Since LIBs today reach maximum energy densities of over 100 Wh / kg, the applicable maximum permissible gross weight of 500 g per LIB is of secondary importance. For Li-metal cells / batteries, however, with up to 4.5% Li by weight the threshold is already reached in cells of less than 25 g / 50 g batteries.
[17] Packing with fully closed walls.
[18] Since Li-metal batteries can hardly be ruled out, both UN numbers are usually required.

E-RECMET

Heinz Böni / Patrick Wäger / Stefan Grösser / Marie Brechbühler Peskova

Indium and neodymium: Does recycling make sense?

The E-Recmet project, which is funded by the Federal Office for the Environment (FOEN) as part of the promotion of innovative environmental technologies, has been running since 2013. The project addresses the issue of the recovery of critical metals from electronic waste (see Technical Report 2013). The focus is on the chemical elements indium and neodymium found in displays and magnets, among other items. Both are considered geologically rare and critical to future supply. The research question this project will answer is: Is the recovery of indium and neodymium technically feasible, economically viable and ecologically sound, and should these scarce metals be recovered in the recycling of waste electrical and electronic equipment?

The recovery of critical metals especially from waste electrical and electronic equipment is a major talking point: The legislator demands it, the media takes up the issue on a regular basis and research is experiencing a veritable boom in projects that study the quantities and importance of these metals in the products as well as their recovery. Since the increasing flow of waste electrical and electronic equipment for disposal can be compared to a resource-rich mine, the question inevitably arises as to whether recycling should also be promoted for metals where the market does not (yet) offer profitability: Despite the scarcity and rising prices, the cost of recycling is usually higher than the income from recovery with the result that these metals may be consumed and may no longer be available as a secondary resource for future generations.

While most projects are devoted to the technical feasibility of the recovery of critical metals, the E-Recmet project had a more comprehensive ambition regard to the technical feasibility of the recovery of various critical metals, only the pre-treatment of waste electrical and electronic equipment that takes place in Switzerland was investigated; in addition, however, the environmental impacts of primary and secondary extraction and economic viability were also analysed. In a first step, of 31 scarce and critical metals contained in electronic components, the metals indium and neodymium were selected to be more closely examined during the further course of the project. These 2 metals acted as representatives of the 31 metals. The aim was to determine, based on two case studies, whether recovery is technically feasible, ecologically sound and economically viable.

Technical feasibility

In Switzerland, waste electrical and electronic equipment is subjected to manual and mechanical pre-treatment. The further processing and recovery of a large number of metals - with the exception of iron – takes place in other European countries. The aim of pre-treatment is to create the best conditions for the recovery of the most important metals from electronic waste by means of an economically and technically optimised combination of manual dismantling and mechanical processing. Thus of around 36 metals found in electronic waste, today approximately 17 metals are already recovered in highly specialised smelting plants. This does not include the rare metals indium and neodymium, among others. The central question in E-Recmet was therefore: What is the optimal pre-treatment for these metals to allow recovery?

In the case of indium, the research showed that the manual liberation of indium-containing LCD panels produces a better material fraction than the mechanical processing of whole screens because in the mechanical process part of the indium is lost and the remainder is also distributed across different fractions. Recovery efficiency at the pre-treatment stage is thus already significantly lower and the resulting target fraction also contains less indium, which complicates and significantly raises the cost of subsequent treatment steps. The recovery of indium will therefore have to be based on manual or at best semi-automatic pre-treatment steps. Since flat screens today are already dismantled manually in order to remove the mercury-containing backlighting, manual pre-treatment would not entail additional costs.

In the pre-treatment of neodymium-containing components of waste electronic equipment, it has been found that the time required for manual liberation of the magnets from disk drives, loudspeakers and headsets is high. Mechanical pre-treatment trials were only partially performed as part of the E-Recmet project due to a shortage of resources. However, research by Umtec at the Technical University of Rapperswil as part of the ongoing Neorec project suggests that an increase in efficiency could be possible by using simple mechanical processes.

In principle, the technical feasibility of the recovery of the metals indium and neodymium at the pre-treatment stage is given. For intermediate and final treatment on an industrial scale, however, some questions that could not be addressed by the E-Recmet project need to be clarified. Several research projects are currently looking into this issues, especially in Germany and Japan. Preliminary tests on a lab and a pilot scale indicate the feasibility of recovering indium and neodymium; today, however, this can still not be taken for granted. The next few years will show whether technical feasibility is given along the entire recovery chain.

Environmental impacts of primary and secondary recovery

With the help of life cycle assessments, an investigation was carried out into the environmental impact of the recovery of 1 kg of indium from flat screens and 1 kg of neodymium (oxide) from hard disk drives compared to the environmental impact of primary production, i.e. the extraction of these metals from minerals.

It was found that the recovery of indium after manual dismantling somewhat outperforms today's primary production (indium is extracted as a by-product of zinc), while the recovery of indium after mechanical treatment has a greater environmental impact than primary production. If in future indium were no longer to be extracted as a by-product, as it is today, but rather as the main product, possibly due to a strong increase in demand, primary production would, however, perform worse than both recovery processes by a wide margin (manual dismantling or mechanical pre-treatment of flat screens prior to further wet chemical processing).

In the case of neodymium (oxide), the life cycle assessment showed that both recovery by manual dismantling and mechanical processing of hard disk drives give considerably better results. The environmental impact of the recovery of neodymium (oxide) from hard disk drives is up to three times less than the environmental impact of the recovery of indium from flat screens.

Economic viability

The questions facing the economic analysis were: (a) How would the Advance Recycling Fee (ARF) change if Swico were to recover indium from screens in future? (b) What is the potentially recoverable amount of indium from screens? To answer these questions, in cooperation with Swico and Empa the Technical University of Bern carried out an economic analysis on the recycling of indium from flat screen equipment.

The analysis covered the product categories "TV monitors," "PC monitors" and "Laptops" and was simulated with the aid of a system-dynamics model. To take account of the uncertainties in the available data on indium recovery and to examine the impact of a change in key model assumptions, a total of seven scenarios were defined. Table 1 and Figure 1 provide an overview of a selection of simulation results.

Change of the ARF in the recovery of indium

Full coverage of the cost of indium recycling with manual processing would lead to an increase in the ARF of approximately CHF 0.19 / product for TV monitors, approximately CHF 0.07 / product for PC monitors and approximately CHF 0.08 / product for laptops (Scenario 1). Table 1 shows two other main scenarios and associated sub-scenarios. Mechanical processing of waste electronic equipment for the recycling of indium would result in much higher costs than for manual processing.

Table 1: Required change in the ARF to cover the cost of indium recycling

Change in ARF (in CHF)	TV Monitors	PC Monitors	Laptops
Scenario 1: Type of processing for the recovery of indium			
Scenario 1a: 100% manual processing	0.19	0.08	0.07
Scenario 1b: 100% mechanical processing	3.52	1.44	1.28
Scenario 2: Costs for the recycling of indium			
Scenario 2a: Cost reduction if In concentrated 50% less	0.06	0.03	0.02
Scenario 2b: Cost increase if In concentrated 200% more	0.45	0.18	0.16
Scenario 3: Change of the take-back ratio			
Scenario 3a: Reduced take-back rate (normal values *80%)	0.15	0.06	0.06
Scenario 3b: Reduced take-back rate (normal values *60%)	0.11	0.05	0.04

Amount of indium potentially recoverable from display devices

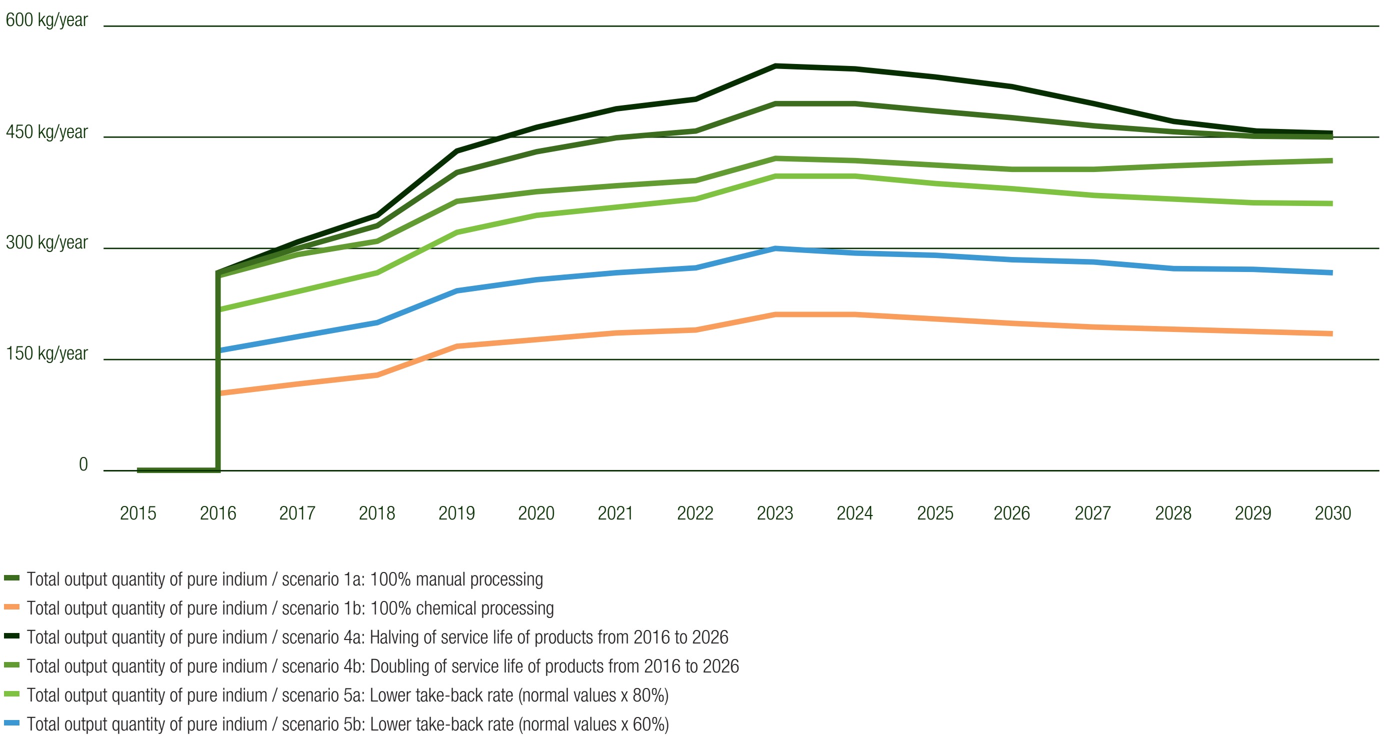
The scenario analyses of the annual output amounts of pure indium take account of the period from 2016 to 2030 (Figure 1). With fully manual processing and a high take-back rate (80% for monitors, 90% for laptops), up to 475 kg of pure indium can be recycled in reference year 2026 (Scenario 1). Under the same conditions, with mechanical processing only 200 kg could be recovered in 2026. The following only considers scenarios with manual processing. With a doubling of the service life of monitors, 406 kg / year of indium could be recovered in 2026 (Scenario 4); with a halving of the service life this figure would be 518 kg / year. If the take-back rate were lower by 20% or 40%, with fully manual processing the amount of indium recovered in 2026 would fall to 380 kg / year or 280 kg / year, respectively (Scenario 5).

The scenario analyses show that with manual processing only a small increase in the ARF (by approximately CHF 0.2-0.5 / product) would be needed in order to recover indium from monitors. The potential amount of recoverable indium from 2016 is likely to be between 300-400 kg per year. These results should be considered against the background of the assumptions made. The assumptions about the actual recovery costs of indium from fractions are not known and therefore had to be estimated. A second important assumption in the analysis of economic viability is that recovery is technically feasible.

Outlook

The E-Recmet project will be completed in mid 2015. The positive results confirm that the recycling of indium and neodymium would be ecologically sound and economically viable. However, the framework conditions on the technical side are not yet fully given. The results of the E-Recmet project will therefore not immediately affect Swico's recycling strategy. In the event of positive developments regarding technical feasibility, however, Swico and the signatories to the Convention (manufacturers, importers and the trade) will in the medium term face the question of what contribution the systems can make to the recovery of critical metals that can not be recovered in a cost effective manner.

Figure 1: Development of recovered amounts of indium in simulated scenarios



COST STUDY

Hannes Zellweger / Deepali Khetriwal / David Rochat

Is Switzerland a high-price country in WEEE recycling?

Excelling at collection

Switzerland, with its long-established take-back and recycling systems for waste electronics and electrical equipment (WEEE), achieved a collection rate of 16.87 kg per inhabitant in 2013, among the highest in the world. Comparing the latest available figures for neighbouring Austria, France, Germany, Italy, the Swiss collection is by far the most proficient. In comparison to Netherlands and Sweden, both with similarly long-established systems, the Swiss systems collectively take-back twice as much as in Netherlands and come only second to Sweden's collection rate of 17.64 kg per inhabitant.

	Switzerland	Austria	France	Germany	Italy	Netherlands	Sweden
Population [million]	8.03	8.41	65.58	80.33	59.39	16.78	9.55
Total WEEE collected in [1000 tons]	135.57[1]	77.40[3]	455.21[3]	690.71[3]	497.38[3]	133.,69[2]	168.61[3]
Per capita WEEE collected [kg/inh]	16.87	9.21	6.94	8.60	8.37	7.,96	17.64

Sources:
Population: Eurostat
Total WEEE collected includes all 10 WEEE Directive categories
1 Data from 2013. From Swico, Sens and SLRS 2013 annual reports
2 Data for 2013. From Wecycle annual report (Kengetallen en jaarrekening 2013)
3 Data for 2012. France, Sweden, Italy, Germany and Austria data from Eurostat

Between a rock and a hard place

Yet, the Swiss producer responsibility organizations (PROs) – Swico, SENS eRecycling and SLRS – are regularly confronted by international manufacturers regarding higher Advanced Recycling Fees (ARF) in Switzerland as compared to other European countries, with pressure to reduce them. This is despite the fact that ARF in Switzerland has continually reduced over the past years. Currently, the large majority of electronic and electrical products have an ARF of less than 1 CHF, with over 80 % of products attracting 2 CHF or less as ARF. Even so, ARF on most products is significantly higher in Switzerland. For example, ARF for mobile phones in Switzerland is only 0.1 CHF per phone (0.095 EUR), yet in France it is even lower, ranging from 0.01 EUR to 0.07 EUR per phone. Similarly, ARF on air-conditioners ranges from 4.51 EUR in France to 17 EUR in Netherlands compared to 24.9 EUR in Switzerland.

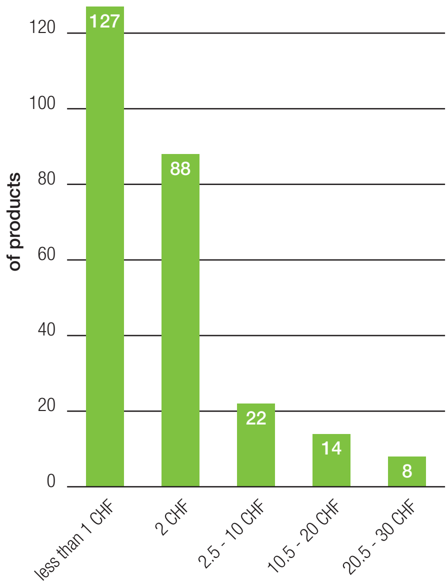


Figure 1: ARF in Switzerland for 2015
[Source: Swico and Sens]

The ARF essentially finances collection, logistics, recycling, audits, PR, monitoring and system administration. Of the approximately 70 million collected in 2013 through the ARF by the three PROs, the largest share – 38% – goes to recyclers for ensuring safe treatment and recycling. Yet, there is pressure from recyclers demanding sufficient compensation in order to cover their costs. However, PROs in other countries have comparatively lower costs for treatment and recycling, with some even earning revenues from the recyclers rather than making payments. An example is the Dutch PRO Wecycle that reported revenues of 43 EUR from recyclers in 2013 (Kengetallen en jaarrekening 2013).

The Swiss PROs therefore find themselves between a rock and a hard place, with pressure from their member companies to reduce ARF on the one hand and demands from their recyclers to the augment payments on the other hand citing high operational costs. And at the same time, the main objective remains to continue operating one of the best-performing systems in the world.

Comparing apples with apples

Consequently, Swico, Sens and SLRS have jointly commissioned a study to better understand the cost structure of the Swiss system and compare it with other systems in order to know if the cost of recycling in Switzerland is genuinely higher and therefore can justify the higher ARF, or not. Simply comparing systems on the basis of apparent costs is like comparing apples with oranges because this does not reflect implicit framework costs (e.g. salary levels, taxes), externalised costs (e.g. public subsidies), differences in scope and product coverage (e.g. whether battery disposal is included) or legal requirements for treatment and disposal (e.g. manual depollution of hazardous fractions). Therefore, to ensure comparability at a system level, a strict methodology has been defined allowing for the main hypothesis explaining the Swiss cost structure to be verified.

In a first step, a breakdown of costs at each stage from collection to treatment and disposal will be made for the Swiss systems as well as a selection of European systems, and parameters influencing costs at each stage will be investigated. This will also include investigating whether higher costs are due to higher collection rates, whether they can be explained due to differences in the material composition, and whether larger countries benefit from economies of scale. The expected results from this investigation phase will allow identifying at which stage the Swiss system is apparently more expensive than its European counterparts, and what are the cost factors that can be influenced by the PROs.

In a second step, the study will also take a closer look into the cost-benefit model of recycling to better understand cost and revenue drivers. On the cost side, this will include estimating average costs under major cost heads such as capital, labour, energy, transport & logistics, plant & maintenance, disposal, compliance and administration costs. On the revenue side, based on the composition of the collected waste stream and commodity market prices, the material value potentially realised will be estimated, also taking into account price volatility and currency fluctuations. The results produced in this second phase will allow for a better understanding of how the treatment and valorisation of WEEE material fractions can be optimized.

The data for this study will include primary data collection through interviews with and questionnaires to selected stakeholders as well as secondary data available publicly through reports and publications. Results are expected to be made available in the course of Summer 2015.

MARKET BASKET ANALYSIS

Andreas Tonner

MBA 2.0 – Big data has arrived in market basket analysis

What is the service life of electrical and electronic equipment? Which devices arrive for take-back and when? Are there regional differences? Do sales of new equipment influence the return flow of old equipment? Or do certain IT / CE devices not even come back for recycling? Do the calculations for the advance recycling fee add up?

Answers to all these important questions are provided through a complex process of data acquisition and evaluation, i.e. market basket analysis or in short: MBA. Around two per cent of the units taken back are analysed, which with a flow of goods of 60,000 metric tons per year corresponds to approximately 1,200 metric tons. In certain locations and on certain dates, electrical and electronic equipment from the Swico mix is segregated into 19 categories. The result shows the devices taken back via the disposal channel neatly broken down by device types, quantities and weights.

Knowing what devices are in the disposal channel is of vital interest for Swico: whether as a basis for calculating the advance recycling fee (ARF), calculating the recycling price or as a benchmark. The question is justified: Are the findings from two per cent of the quantity taken back sufficient to draw conclusions for the remaining ninety eight percent? One thing is clear: the more extensive and detailed the data collection, the more certain and more accurate the resulting analysis.

MBA 2.0

At the end of 2013, Swico decided to expand market basket analysis and record a greater flow of goods with more detail. The goal, initially in a trial run, was to record 20 % of the flow of goods from the indirect channel in the market basket analysis. All equipment was to be weighed and recorded by origin and type and the data made available on a central database for all kinds of evaluation.

It was not possible to perform this task with the existing resources. A process with a completely new system setup had to be developed: a combination of two parallel operating computer-aided weighing systems and online data acquisition via touchscreen. The scales equipped with their own web have a measuring range of 0.001 to 1,500 kilograms.

The MBA 2.0 system has been in service since February 2014. Findings and recommendations were continuously implemented in the system. Optimised workplace ergonomics and Internet speed led to shorter throughput times, and the initial 19 equipment categories were extended to 36 with additional sub-groups, accessories and components. After a ten month test phase, the MBA 2.0 system is stable in operation and provides reliable, comprehensive and detailed information on IT and CE equipment in the disposal channel.

Big data has arrived in Swico market basket analysis. The collection and analysis of data sets from the disposal channel is becoming more demanding and can only be accomplished with the latest technology. The MBA 2.0 system not only enables efficient recording, but also offers comprehensive access to the data. The data can be better analysed and better use can be made of the findings from the analysis.

The next steps are already in preparation. In addition to the stationary MBA for the indirect channel, mobile market basket analysis (MBA 2.1) will be introduced for the direct channel. Thus, the flow of goods can be recorded directly at the collection point. The start of this is planned for the second quarter of 2015. Customised data collection, for example by manufacturer, product, serial number or equipment condition, even including photographic recording, is not merely wishful thinking for the future, but is becoming a reality.

Ueli Kasser

Mercury in high pressure sodium vapour lamps (HPSV)

High pressure sodium vapour lamps (HPSV) as used in street lighting are quantitatively not very significant in terms of lamps in general. In Switzerland, it is estimated that around 20 tons are taken back for controlled disposal each year. However, the disposal of this comparatively small amount is a challenge. The problem lies mainly in the fact that these HPS contain high levels of mercury in the form of sodium amalgam. An investigation in cooperation with Batrec Industrie AG[19] clarifies the relationships and environmentally sound disposal.

Figure 1: 20 targeted samples from 15 pallets of HPS lamps.

In conventional mechanical processing of whole high-pressure sodium vapour lamps (PSV)[20], in particular the fractions are contaminated to an extent which does not meet the standards prescribed by SENS[21]. It appears difficult to keep the mercury concentrations low, even for the glass fraction. As part of a small project the possible causes of high levels of mercury were to be clarified. According to a market basket analysis from 2010[22], approximately 6 % HID (High Intensity Discharge) is to be found in the waste of non-tubular lamps. With 413 t (2013) this would result in about 24 t HID. This figure is probably too high, because the share of energy-saving lamps increased greatly from 2010 to 2013. HPSV is the most common type among HID lamps.

Targeted samples from 15 pallets

From a population of 15 pallets of HPS lamps (see Figure 1), 20 samples of 2 lamps each were selected in a targeted manner. They differed in the following aspects:

- 6 different manufacturers
- 70 to 940 W capacity
- Producing countries (Belgium, China, Slovakia, USA and Germany)
- Types and designations "Hg-free"

All common types from different manufacturers and countries were represented in the 20 samples. An example of a sample is shown in Fig. 2. To simplify the analysis, the HPS lamps were broken

Figure 2: Example of an HPSV sample.

and the mercury content was measured on the arc tubes only. These are made of quartz or ceramic materials and were ground to <0.1 mm, digested with acid and measured by atomic absorption spectroscopy AAS. Sample preparation and analysis took place in the laboratory of Batrec Industrie AG, two of each of the duplicate samples were analysed in an external laboratory. The temperature programmed desorption (TPD) method was not effective for Na-Hg amalgam.

No relationships identified

The mercury contents vary within a wide range and no direct relationship can be identified with the manufacturer, service category, place of production or lamp shape.

Table 1: Hg mass fraction in arc tubes of HPSV lamps (number of samples in brackets)

Manufacturer	Hg mass fraction
Lucalox (4)	25 – 370 ppm
Osram (6)	40 – 4800 ppm
Philips (6)	16 – 2600 ppm
Others (4)	60 – 2600 ppm

Capacity range	Hg mass fraction
70 W (5)	16 – 2600 ppm
150 W (6)	30 – 4800 ppm
250 – 940 W (6)	16 – 2600 ppm

Converting the Hg mass fraction in the arc cells to the total Hg content results in a mass of <1 to 28 mg per lamp. However, it must be assumed that part of the mercury was already released into the environment in the course of the destruction and grinding of the cells. Thus, the effective Hg quantities in the lamps are likely to be higher.

New HID also have high mercury levels

New high pressure sodium vapour lamps also contain mercury levels that hardly allow purely mechanical treatment. Table 2 lists a number of new, stated as REACH compliant, randomly selected HID lamps from the Osram website.

Mercury plays an important role in virtually all HID technologies associated with plasma formation in the arc. In older technologies, mercury was often also required to dose sodium in the form of the amalgam during the manufacturing process. Low pressure sodium (LPS) lamps do not contain mercury, but are of little importance. According to statements by manufacturers, this situation will not change in the medium term even with new lamps, as no replacement for the specific properties of mercury is in sight. The replacement of HID with LED technology is also expected to take more development time. With HID lamp waste, therefore, it will be necessary to adjust to increased levels of mercury for longer periods.

Figure 3: Sodium amalgam deposits in the cooled arc tubes of an HPSV lamp.

Plausible results

The differences that were found in the measurements of Hg in HPSV lamps can be explained by the cooling and the simplified analysis used in this study. The plasma temperature of sodium and mercury in the arc tube is several thousand degrees when in use[23]. On turning off, the mercury amalgam condenses where the high pressure cell is coldest. This mainly occurs at the ends on the inside of the ceramic or quartz tubes immediately adjacent to the electrodes (see Fig. 3). Therefore it is crucial how much of these deposits is captured when separating the ceramic from the tungsten electrodes. Since these relationships were not known when defining the simplified analysis large measurement errors might have occurred. The electrodes are mainly made of tungsten, which does not form amalgam with mercury. According to statements by experts, very little or no mercury penetrates into the ceramic. The contamination of the fractions can also be explained in this context. Normal glass and the ceramic of the arc tube can not be separated in this process. Lamp fractions soon become contaminated with highly concentrated sodium amalgam.

Thermal process step required

With regard to the disposal of HID and HPSV lamps the following conclusion can be drawn:

- HID lamps can not generally be treated in purely mechanical processing systems mixed with other non-tubular lamps.
- Sorting of Hg-containing and Hg-free HID lamps is impossible and unnecessary in light of the fact that Hg-free lamp types are of secondary importance in HID technology.
- In order to achieve environmentally sound disposal without fugitive mercury emissions, treatment of arc tubes, including the penetrating tungsten electrodes, at elevated temperatures and with mercury separation is indispensable.
- The recycling of metal fractions is permitted provided that the limits of the technical regulations under the SENS agreement are observed. Parts not contaminated with mercury such as the metal thread, rod or outer glass can be separated beforehand. This would enable a more rational treatment of the arc cells. However, to date only semi-mechanical processes for separating the outer glass are known.

Stated Hg content of new HID lamps

Designation according to Osram offering	Capacity range	mg Hg / unit
High pressure sodium vapour lamps (HPSV)	50 – 1000 W	18 – 58
Low pressure sodium vapour lamps (LPS)	18 – 180 W	0
Halogen metal vapour lamps, ceramic technology	20 – 250 W	3 – 45
Halogen metal vapour lamps, quartz technology	20 – 250 W	12 – 220
Mercury vapour lamps	50 – 1000 W	12 – 79
Mercury blended lamps	150 – 500 W	16 – 41

[19] In cooperation with Dr. Norbert Dawidowsky and Xavier Ibarz Formatger, Batrec Industrie AG - Wimmis

[20] Regarding terminology: Whereas in Switzerland the term lighting equipment is in common use, in Germany the term lamps is used; both terms are used synonymously here.

[21] 5 ppm Hg for the glass fraction, 10 ppm for metal fractions according to Technical Regulations SENS/ Swico, Version 1.1, 2012.

[22] Gasser, D.; Market Basket Analysis SLRS – Campaign OeSS 2010, Analysis of the composition of non-tubular lamps, SENS Zürich 17.10.2010.

[23] Tóth+, Lovas, H.; Chemistry of materials science phenomena in high-intensity discharge light sources; Pure Appl. Chem. Vol. 79, No10, pp 1771-1778, 2007.

PHOTOVOLTAICS

Roman Eppenberger

Recycling of photovoltaics assured throughout Switzerland

The taking back of photovoltaic systems has been assured since the beginning of cooperation between SENS and Swissolar. Now, from 2015, the nationwide collection network of SENS in Switzerland has been integrated into the collection process. The recycling of photovoltaic systems is thus guaranteed and the material cycle is closed.

Swissolar and SENS eRecycling

The trade association Swissolar is devoted to the policy issues of the solar energy industry. The approximately 500 members are made up of energy suppliers, research institutions, representatives of other organisations and around 120 specialist companies.

The VREG has been in force since 1998 and is currently being completely revised. An important point in the revision is the inclusion of additional equipment categories such as photovoltaic (PV) equipment in the catalogue of equipment for disposal. Through this revision, the recycling of photovoltaic systems will also be financed by the advance recycling fee (ARF) in the future.

SENS eRecycling begins with taking back

SENS eRecycling has been taking back PV modules since 2014. Until now, these take-backs were triggered by an e-mail or fax from the submitter. Since January 2015, the necessary processes have been put in place and smaller quantities of PV modules can be handed over at all SENS collection points.

Plant dismantlers, which have to dispose of large amounts of PV modules, can report to SENS using a PV collection request. The placing of a container at the dismantling site and collection are free of charge.

The PV modules, which are collected via the SENS collection network throughout Switzerland, are transported from there to special PV collection points and put into interim storage. Once there is sufficient material at the PV collection points, the PV recycler is instructed to transport the material to the PV processor in a large load.

Composition of photovoltaic modules

Depending on the PV technology used, photovoltaic module mass consists of approximately 90 percent glass. Metals such as copper or aluminium and plastics make up about another 10 %. The actual core of a solar module, i.e. the semiconductor, comes in only very small quantities. In silicon-based modules, the semiconductor accounts for around 2 %. In non-silicon-based modules, the semiconductor content decreases to about 0.1 % -1.15 %. The trend in the PV industry shows that more and more producers will produce still thinner semiconductor layers. With today’s technology, between 80 % and 90 % of module weight can be recovered for the production of new materials.

Recycling of photovoltaic modules

Since photovoltaic modules consist mostly of glass, they are processed as part of flat glass recycling (similar to car windows). There is no flat glass recycler in Switzerland.

The great art in flat glass recycling lies in the best possible separation of glass and laminated film, which is closely applied to the glass for the stability and protection of the module. However, laminated films in the recycled glass fraction reduce the selling price. Therefore, very special mechanical processes are required to perform the separation of glass and laminated foil in an economically sound manner.

No hazardous substances in photovoltaic modules

Silicon-based and most non-silicon-based photovoltaic modules do not contain harmful substances. And if photovoltaic modules containing hazardous substances do find their way into the take-back process, they are singled out and treated with special chemical processes before they can be introduced into the normal PV treatment process.

Emil Franov

Where next for the recycling rate?

High recycling rates in the processing of waste electrical and electronic equipment are critical for the purpose of demonstrating significant environmental benefits. The minimum rates defined by SENS, Swico and SLRS range from 50 to 80 % depending on the equipment category and meet the requirements of the EU WEEE Directive. The rate increase of 5 % set by the EU for almost all equipment categories should not represent too great a hurdle for the local operators because many already satisfy more stringent values. With the increased replacement of metals by difficult to recycle plastics in electrical and electronic equipment, however, recycling operators will have no choice but to separate plastics for material recycling.

In order to generate the greatest possible environmental benefits, a high level of material recycling – expressed in the recycling rate – is the most important criterion in the recycling of WEEE. In particular, the recovery of metals plays a major role due to the high level of environmental contamination in their production. By returning recovered scrap metal to the material cycle, the emissions that arise in the production of metals from ores can be avoided (e.g. heavy metal emissions during ore mining, air pollution from the provision of energy for ore processing).

According to EU Directive 2008/98/EC on waste, recycling means "any recovery operation by which waste materials are processed into products, materials or substances whether for the original purpose or for other purposes". It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are intended for use as fuels or for backfilling". After recovery and recycling rates were introduced in the EU in 2003, the Technical Commission of SENS, Swico and SLRS decided to refine the previous calculation of the recycling rate. Until that time, the recycling rate was calculated on the basis of the annual material flow data. This method still makes sense today for specialised recycling operators which process only a single equipment category. For recycling operators which process several equipment categories, this method is too imprecise because similar fractions from the processing of different equipment categories are not recorded separately for cost reasons.

It soon became apparent that the batch trials performed for the first time in 2004 constituted a very good basis for the recalculation of the recycling rate, as well as for the more accurate determination of material flow data from large shredder operations. In the following years, batch trials were carried out in all mechanical processing plants and the recycling rates were calculated with a specially developed Excel tool. The calculation tool was later superseded by Reptool, a web-based application.

On average, the recycling rate for WEEE of all equipment categories has remained constant for several years at about 75 %. The following minimum rates are prescribed for the individual equipment categories:

WEEE Directive Category	Equipment Category	Recycling rate
1	Large household appliances including refrigerators	75 %
2	Small household appliances	50 %
3	IT and telecommunications equipment	65 %
4	Consumer electronics	65 %
5a	Lamps and light fittings	50 %
5b	Illuminants and gas discharge lamps	80 %
6	Electrical tools, building, garden and hobby equipment	50 %
7	Toys and sport and leisure equipment	50 %
8	Medical equipment	no data
9	Monitoring and control instruments	50 %
10	Automatic dispensers	75 %

From 15 August 2015, the required recycling rates in the EU for all categories of equipment except gas discharge lamps will be increased by 5 %. This development was to be expected because in the past decade the recycling technologies for processing WEEE have advanced on all levels. Most recycling companies in Switzerland have brought themselves up to the appropriate technical standard in good time and today already meet the stricter recycling rates.

However, it must be borne in mind that the achievement of these recycling rates can by no means be taken for granted, for there are still a number of trends that complicate the task. Thus, in particular – but not alone – in the quantitatively significant equipment category of large household appliances, a trend to replace metal with plastic components has been discernible for some time. Plastics are more difficult to recycle than metals, among other things because of the in part still existing contamination with toxic flame retardants. However, several recycling companies today already convey a considerable proportion of plastics into the material recycling process, which shows that innovation has not stood still here either.

In the light of these developments, it is clear that, in addition to the preferably loss-free recovery of all metals, plastics recycling is becoming increasingly important to the achievement of the required recycling rates in the longer term.

Material recycling of plastics from WEEE is becoming an increasingly important factor when it comes to achieving the required recycling rates in the longer term.

AUTHORS

Heinz Böni

After graduating as a Rural Engineer at ETH Zurich and completing a postgraduate degree in Sanitary Engineering and Water Protection (NDS / EAWAG), Heinz Böni worked as a researcher at EAWAG Dübendorf. After working as project manager at the ORL Institute of ETH Zurich and at UNICEF in Nepal, Heinz Böni was appointed to manage the branch office of the engineering company Büro für Kies+Abfall AG in St. Gallen. He then spent several years as co-owner and managing director of Ecopartner GmbH in St. Gallen. Since 2001 he has been at Empa, where he heads the CARE group (Critical Materials and Resource Efficiency) and ad interim the Technology and Society Lab. He has been Head of the Conformity Assessment body of Swico Recycling since 2009 and an auditor for Swico and the SENS Foundation since 2007.

Prof. Dr. Marie Brechbühler Pešková

Marie Brechbühler Pešková studied economics and management in Prague (Czech Republic) and Stockholm (Sweden) and gained her doctorate at the University of Fribourg (Switzerland). After several years in the consulting business (notably in the field of environmental economics at Ernst Basler and Partner, Zollikon) she returned to the academic world in 2007. Since then she has been working as a lecturer in the Faculty of Economics at Bern University of Applied Sciences. Her subject areas include in particular "Sustainability Strategies" and "Sustainable Supply Chain Management". She is responsible for the research field "Future Economic Shortages" and conducts research in the field of critical resources (e.g. rare metals) and their economic importance, as well as in other areas.

Dr. Deepali Khetriwal

Deepali Khetriwal received her doctorate from the University of St. Gallen with a thesis on forecasts of waste flows of end-of-life consumer goods. Prior to her doctoral studies, she gained an MBA in International Management at the University of St. Gallen. She began her work in the field of "e-waste" at Empa and worked on the Swiss electrical and electronic waste programme from 2004-2009. Since that time, Dipali Khetriwal has worked on various projects around the world that are related to electrical and electronic waste. In particular, she was instrumental in capacity building under the auspices of the "E-waste Academy" of the StEP initiative, which is a UN-supported forum for the field of electrical and electronic waste.

Roman Eppenberger

Roman Eppenberger graduated as an Electrical Engineer (dipl. El.-Ing.) at ETH Zurich. In tandem with his professional career, he completed the postgraduate Executive MBA at the East Switzerland University of Applied Sciences. He gained his first industrial experience as an engineer and project manager in the area of robotics in the fields of medicine and pharmacy. As a product manager, he joined the contactless division of the Legic company (Kaba), where he was responsible for global purchasing of semiconductor products. Since 2012 Roman Eppenberger has been employed by the SENS Foundation as an executive board member and heads up the Operations department. In this capacity he coordinates the Swico / SENS Technical Commission in conjunction with Heinz Böni.

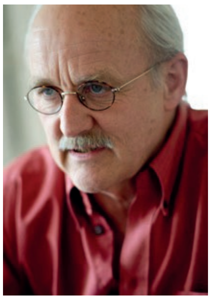
Prof. Dr. Stefan N. Grösser

Dr. Stefan N. Grösser is Professor of Strategic Management at the Institute of Corporate Development at Bern University of Applied Sciences, where he heads the "Strategy and Simulation Lab" with a research focus on "Strategic Analysis and Decision-Making in Dynamic Systems". Prof. Grösser is also project manager of the application-based research projects of the Swiss electricity industry and the clean-tech sector. Since 2013 he has headed up a sub-project of the EU research project "use-it-wisely" (www.use-it-wisely.eu); a strategic innovation management project with 20 European partners.

He completed his academic education at the University of Stuttgart (Graduate of Business Administration with a technical bias), at the University of Bergen (M.Phil.), Norway, and at the University of St. Gallen, Switzerland (Doctorate in Business Economics, Dr. oec. HSG). He was a visiting research fellow at the System Dynamics Group of the Sloan School of Management, Institute of Technology (MIT), USA. His research has been published in international peer-reviewed journals and by publishers such as Wiley, Springer and Gabler (www.stefan-groesser.com).

Dr. Geri Hug

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



Ueli Kasser

Graduate in Chemistry (Dipl. Chem.) / lic. phil. nat. at the University of Bern and ETH Zurich and graduate of INDEL (postgraduate course on problems of developing countries). After initially working as a freelancer in the fields of radioecology, ecotoxicology and occupational hygiene, he became co-owner of ökoscience – a consultancy office for applied ecology in Zurich - and project manager in the areas of air quality, environmental consulting and ecotoxicology. At this current time, Ueli Kasser is the owner of the Office of Environmental Chemistry in Zurich, which specialises in consulting in the fields of waste, chemicals safety, building materials ecology and indoor air quality. In addition to his teaching activity, he is an auditor for environmental management systems according to ISO 14001. Since the mid-nineties, Ueli Kasser has been an inspector of recycling operations on behalf of the SENS Foundation; he develops the standards and guidelines for the inspection activities, represents the SENS Foundation in the European association and acts as consultant in the European Standards project WEEELABEX.

Emil Franov

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

Esther Thiébaud

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

Niklaus Renner

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

David Rochat

David Rochat completed his Master's degree in Environmental Engineering at the Federal Institute of Technology in Lausanne (EPFL, Switzerland) in 2004. He began his career in research at the Industrial Ecology and Life Cycle Group (EPFL) before moving to the Swiss Materials Science and Technology Institute (Empa) in 2005, where he coordinated a number of projects in the field of electronic waste management at the international level. In 2008 he was co-founder of the Sofies company and set up the company's departments of electronic waste management, cleaner production and resource efficiency, where he laid special emphasis on the informal sector in developing countries. Since then David Rochat has worked in the field of e-waste for various clients in more than 15 countries, including the UNDP, UNIDO, the World Bank and major manufacturers. Apart from his expert work on behalf of Sofies, David Rochat is also the company's Director of Business Development.

Andreas Tonner

After commercial training in public administration and subsequent specialist training, Andreas Tonner worked for eight years as an administrative officer in various functions. In 1995 he moved into the waste disposal industry, where until 2007 he worked in the management of Tonner-Altstoff AG, Sereda AG and Texta AG as well as holding a number of directorships. In 2008 he founded Recycling-Coach GmbH, which operates in the fields of consulting and coaching of businesses, associations and public bodies. In 2010 Andreas Tonner founded Oekotech Reco AG, with a focus on material cost optimisation in waste disposal and raw material marketing.

Dr. Patrick Wäger

After studying chemistry at ETH Zurich and subsequently completing a dissertation at the Institute of Toxicology of the ETH and University of Zurich, Patrick Wäger worked for two years as an environmental consultant at the Elektrowatt engineering company in Zurich. Since then he has worked as a research associate and project manager at Empa in numerous research projects on waste disposal and the recovery of raw materials from end-of-life products; he works as an inspector for the SENS Foundation and Swico Recycling and was temporarily also lead auditor for environmental management systems pursuant to ISO 14001. Patrick Wäger has several teaching assignments in the field of environmental and resource management and among other activities is a member of the board of the Swiss Academic Society for Environmental Research and Ecology (SAGUF). The current focus of his work lies in the exploration of strategies for more sustainable use of non-renewable resources, especially rare metals.

Rolf Widmer

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

Hannes Zellweger

After training as an environmental engineer with a focus on Material Balance and Disposal Technology at ETH Zurich, Hannes Zellweger worked at Amstein + Walthert as a consultant on innovative networks of industry and residential areas for efficient, low-emission heating systems. He then spent three years working for the Swiss State Secretariat for Economic Affairs (SECO) and for Empa, St. Gallen, in Peru, where he was involved in various programmes in his core areas of resource and energy efficiency as well as recycling management. Since 2013, Hannes Zellweger has been working for Sofies where he is responsible for business development in German-speaking countries.

LINKS

International links

www.ewasteguide.info
Information and a collection of sources on the subject of 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 the collection and recycling of electrical and electronic equipment.

www.step-initiative.org
Solving the E-waste Problem (StEP) is an international initiative led by the United Nations University (UNU), whose members are not only major players from the fields of production, re-use and recycling of electrical and electronic equipment but also 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 (Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal) of 22 March 1989 is also known as the Basel Convention.

www.weee-europe.com
WEEE Europe AG is a consortium of 15 European take-back systems and from January 2015 allows manufacturers and other market participants to fulfil their different national requirements from a single source.

National links

www.eRecycling.ch

www.swicorecycling.ch

www.slrs.ch

www.swissrecycling.ch
Swiss Recycling is an umbrella organisation which promotes the interests of all active parties in the recycling organisations in Switzerland which are involved in separate collection.

www.empa.ch
The Swiss Federal Laboratories for Material Science and Technology (Empa) is a Swiss research institute for applied materials science and technology.

www.bafu.admin.ch
The Federal Office for the Environment (FOEN) provides on its website under “Waste” a series of helpful information and news about the recycling of electrical and electronic equipment.

Cantons with delegated enforcement

www.awel.zh.ch
The website of the Office for Waste, Water, Energy and Air (AWEL) offers under “Waste, Raw Materials and Contaminated Sites” a range of information that is directly relevant to the recycling of electrical and electronic equipment.

www.ag.ch/bvu
The website of the Department of Construction, Transport and Environment of the Canton of Aargau offers under “Environment, Nature & Landscapes” helpful information on the recycling and recovery of raw materials.

www.umwelt.tg.ch
The website of the Department for the Environment of the Canton of Thurgau offers under “Waste” information relevant to the region with regard to the recycling of electrical and electronic equipment.

www.afu.sg.ch
The website of the Agency for Environment and Energy of St. Gallen provides general information and pamphlets on specific topics and under “Environmental Information” and “Environmental Facts” offers information on current topics.

www.ar.ch/afu
The website of the Agency for the Environment of Appenzell Ausserrhoden provides general information and publications on various topics related to the environment.

www.interkantlab.ch
The website of the inter-cantonal laboratory of the Canton of Schaffhausen offers under “Information on Specific Waste” helpful information on the subject of the recycling of electrical and electronic equipment.

www.umwelt.bl.ch
The website of the Agency for Environmental Protection and Energy (AUE) under “Waste / Waste subject to controls / Electronic waste” offers information on the recycling and recovery of raw materials in electrical and electronic equipment.

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Images
Page 18 Fig.1: Rolf Widmer, Empa
Page 18 Fig.2: Roger Gnos, Swico
Page 24: Andreas Tonner, Oekotech Reco AG
Page 25/26: Batrec Industrie AG
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