Swico, SENS, SLRS

Technical Report 2013

INTRODUCTION

Pacesetter in Europe

Recycling electronic and electrical equipment has become a more serious undertaking with the introduction of the EU Directive WEEE II. Compared with the EU Directive WEEE I, collection quotas are noticeably more demanding: from 2016 at least 45 % of equipment sold in an EU national market must be recycled. From 2019 requirements will be even more more stringent, with the quota moving up to 65 %. Switzerland does not specify such binding collection quotas. Does that mean that our country is lagging behind the EU in terms of recycling end-of-life equipment? If one takes the scope of regulation as a benchmark then perhaps, yes. However, in terms of how the take-back systems operate, we in Switzerland are comfortably outperforming most EU countries and in 2012 achieved a collection quota of well over 75 %.

However, EU countries face a different and more challenging task compared to Switzerland in terms of collection quotas. Firstly, differing cultures either facilitate or hamper the separate collection of equipment. Secondly, our borders are not completely open to the movement of goods, which means the customs authorities have a better control of exports. Thirdly, as a land-locked country we do not have any ocean ports that often play a major part in illegal exports. And fourthly, we have a network of several thousand collection points that enable consumers to easily hand in end-of-life equipment.

In many respects, Europe is a key reference point for the SENS, Swico and SLRS take-back systems. Our commitment is not limited to our active membership in the WEEE Forum, the European Association of Electrical and Electronic Waste Take Back Systems. We also played a considerable part in bringing about a European standard in the form of WEEELABEX, which is about to acquire generally binding force as the official CEN norm. And we are very happy (and not entirely without blame) that the new standardisation is not geared towards the lowest common denominator, but rather that it specifies very high quality standards.

In Switzerland, as in the last few years, co-operation between the three systems is being further reinforced in relation to operations where synergies can be utilised. Stakeholders that co-operate with the three systems are, where possible, to be approached via a single organisation, or at least by using a standardised procedure. This enables us to operate more cost-effectively, and prevents one of the three being played off against the others. This led us to publish a joint Technical Report for the first time last year. The feedback was so encouraging we have decided to publish a joint Technical Report again this year.

Jean-Marc Hensch
Swico

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SENS Foundation, Swico, SLRS: expertise in sustainability

For some 20 years the three take-back systems SENS, Swico and SLRS have been efficiently recycling electrical and electronic equipment. Increasing take-back quantities testify to the successful operation of the three systems.

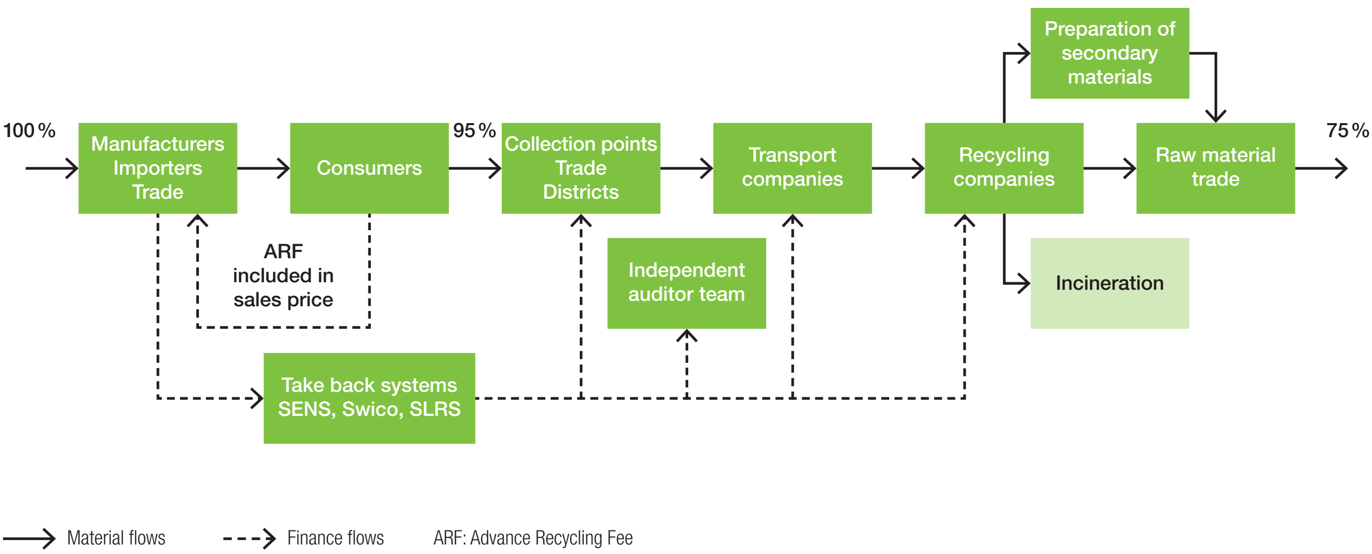
In Switzerland there are three take-back systems for electrical and electronic equipment. There are historical reasons for the existence of three systems. Sector-specific systems were established in the early years of institutionalised recycling. These were aimed at guaranteeing proximity to the respective sector to address their specific requirements. This also meant that initial reservations about what is still today a voluntary system could be broken down. Depending on the type of equipment, recycling is now the responsibility of either Swico, the SENS Foundation or SLRS (the Swiss Lighting Recycling Foundation).

In 2012, the three systems disposed of more than 129,000 tonnes[1] of waste electrical and electronic equipment. As a result, Swico, the SENS Foundation and SLRS also play a significant part in ensuring that valuable resources can be returned to the production cycle. Through their links at European level – for example as members of the WEEE Forum (European Association of Electrical and Electronic Waste Take Back Systems) – they help set standards for the recycling of electrical and electronic equipment, including at cross-border level.

The Swiss Regulation on the Take-Back, Return and Disposal of Electrical and Electronic equipment (VREG) oblige dealers, manufacturers and importers to take-back equipment in their product range free of charge. An advance recycling fee (ARF) is levied at the point of sale of such equipment to competitively finance the sustainable and environmentally conscious recycling of electrical and electronic equipment. The ARF is an efficient financing instrument that guarantees that Swico, the SENS Foundation and SLRS can deal with the professional processing of their respective equipment, and are in a position to face future challenges.

[1] This is the quantity in accordance with the material flow quantities reported by the recycling companies. This is not to be equated with the settled quantity in accordance with the SENS and Swico Recycling business reports or annual reports.

The take-back systems at a glance



Swico

Swico Recycling, a special fund within the Association for Digital Switzerland Swico, deals exclusively with the recycling of e-waste on a cost-covering basis. For example, Swico's activity is aimed at reclaiming raw materials and disposing of pollutants in line with environmental requirements. In that respect, Swico focuses on informatics, consumer electronics, office, telecommunications, graphics industry and measurement/medical technology equipment such as copiers, printers, TVs, MP3 players, mobile telephones and photo cameras etc. A crucial factor in Swico's ability to assert high uniform quality standards in disposal services throughout Switzerland is its close relationship with Empa, a research centre for materials science within the ETH domain.

SENS Foundation

The SENS Foundation is an independent, impartial and not-for-profit foundation. In dealings with external parties it operates under the SENS eRecycling brand. Its operations are geared towards taking back, recycling and disposing of electrical and electronic equipment from the following areas: small and large-scale domestic equipment; building/garden and hobby equipment as well as toys. To that end, the SENS Foundation works closely with specialist networks which represent the parties involved in the recycling of electrical and electronic equipment. In co-operation with its partners, the SENS Foundation aims to bring the recycling of such equipment in line with economic and ecological principles. During the course of 2012, the SENS Foundation's activities led to a successive increase in the quantity of recycled cooling, refrigerating and air-conditioning equipment. Saturation point has yet to be reached in terms of the volume of recycled cooling equipment.

The Swiss Lighting Recycling Foundation (SLRS)

The fundamental system responsibility for lamps and light fittings is held by the Swiss Lighting Recycling Foundation (SLRS). SLRS organises the area-wide disposal of lighting equipment and luminaires throughout Switzerland. To finance these activities, SLRS administers one fund for lighting equipment and one for luminaires. The funds' costs are supported by the respective ARFs. Furthermore, the foundation's activities include training for, and familiarising market participants with, the recycling of lighting equipment and luminaires as well as providing all stakeholders with information. The close partnership between SLRS and the SENS Foundation applies to all areas. For example, as a contract partner of SLRS, its take-back and recycling system means the SENS Foundation not only implements the collections and transport activities at an operational level, it is also responsible for recycling, controls and reporting in relation to luminaires and lighting equipment.

Focus on plastics

In 2012 the joint Technical Commission of Swico and the SENS Foundation focussed squarely on the topic of plastics. As reported in the 2011 Technical Report, it is gratifying to see a sharp increase in the recycling of plastics in the last few years. In 2011 about 16,000 t of plastics from waste electrical and electronic equipment were recycled with a view to recovering materials. In that respect, care is to be taken that materials are recycled in line with valid environmental requirements and in accordance with the technical requirements specified by Swico and the SENS Foundation. This is why particular attention was attached to plastics recycling companies in 2012.

The Technical Commission of Swico and the SENS Foundation comprises ten people and holds all-day meetings four times a year. In addition, the respective autumn meeting is supplemented with further training. Audit results as well as questions that require clarification are discussed during meetings. Technical requirements and applying them uniformly are likewise regular items on the agenda at the meetings. Where necessary, adjustments to the requirements are reviewed, and proposals are put forward to the systems regarding corresponding amendments. The meetings also determine which secondary treatment partners should also be subject to auditing. Secondary treatment partners process e-waste fractions originated from recycling partners of Swico and the SENS foundation. Normally, a content focus is specified. In 2012, the focus was on secondary treatment partners of plastic fractions.

Audits of secondary treatment partners

Each year, Swiss recycling partners are required to provide the Swico/SENS Technical Commission with detailed information about their material flows, which are discussed and reviewed during audits. This ensures that the flows of fractions from the inital processing to the processing partners (usually abroad) are thoroughly documented. This enables the Technical Commission to identify new secondary treatment partners. For example, in 2012 one new processing partner was identified and audited in Germany and the Netherlands each following a audit of a plastics processing company in Austria the previous year. Secondary treatment partner audits – which are similar to audits conducted for the Swiss recycling partners – focus on a review of conformity with the law and compliance with the Swico/SENS technical requirements. This also includes retracing and checking the quantities that Swiss recycling partners have declared in their material flow reports. Secondary treatment partners undertake to furnish proof of the locations they forward their fractions to. These may either be forwarded directly to a manufacturer of new products or to an additional downstream processing company.

Clear requirements apply to the transition from waste to a product. A waste plastic is only deemed a new product if it meets the requirements in Europe set out in the European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). If the plastic is used in a new electrical or electronic product, compliance with the EU Directive on Restriction on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS Directive) is also required. In Switzerland, the provisions are specified by way of analogy in the Chemicals Risk Reduction Regulation (ChemRRV). The legislature places particular emphasis on brominated flame retardants and individual heavy metals. The processes applied in the preparation of plastics must ensure that plastics to be reintroduced to the product cycle meet the requirements. If the foreign companies fail to comply with the technical requirements specified by Swico and the SENS Foundation, the Swiss recycling partner may be prohibited from supplying such a company. Fortunately, this is rarely the case. Usually only minor adjustments are necessary, which are then inserted in the audit record and subsequently reviewed. The audit record is forwarded to the foreign recycling partner and to the SENS Foundation. It is neither forwarded to other recipients nor communicated to outside parties that are the foreign customers of the Swiss recycling partners because selecting these is ultimately a competitive matter. However, a central plank of these technical requirements specifies that the recycling partners of Swico and the SENS Foundation "… are responsible for the dismantling companies working on their behalf and the secondary treatment partners taking in fractions for external further processing and similarly for compliance with the regulations set out in the technical requirements." (Excerpt from the technical requirements).

Continuous further training

Last year, the further training provided by the Technical Commission also focussed on the topic of plastics. In that respect, the life cycle assessment of electrical and electronic recycling were presented and discussed. Scientific studies conducted by Empa have shown that the provision of secondary plastics from processing electrical and electronic waste creates lower environmental pollution by a factor of three compared to providing the same quantity of raw materials from primary plastics. An external speaker, Chris Slijkhuis (formerly MBA Polymers), was also invited to the further training session and illustrated the significance and risks of the use of plastics from an overall European viewpoint.

Heinz Böni

After graduating as an agricultural engineer at ETH Zurich, and a post-graduate course in domestic waster supply construction and water conservation (NDS/EAWAG), Heinz Böni worked as a research associate at EAWAG Dübendorf. After holding the position of project manager at the ORL Institute of ETH Zurich and a stint at UNICEF in Nepal, Heinz Böni took up the position of Managing Director of Büro für Kies+Abfall AG in St. Gallen. After that he was a co-owner and managing director of EcoPartner GmbH St. Gallen for several years. He has been at Empa since 2001, where he is head of the CARE (Critical Materials and Resource Efficiency) group and interim head of the Technology and Society department. From 2009 he has held the position of Head of the Technical Audit Department of Swico Recycling, and has been an audit expert for Swico and the SENS Foundation since 2007.

Roman Eppenberger

Roman Eppenberger completed his studies at ETH Zurich, graduating as an electrical engineer. In tandem with his professional activities, he completed the post-graduate course Executive MBA at Fachhochschule Ostschweiz. He gained his first industrial experience as an engineer and project manager in the field of medical and pharmaceutical robotics. As a project manager, he moved to the Contactless Division of the company LEGIC (KABA), where he was responsible for the worldwide purchasing of semiconductor products. From 2012 Roman Eppenberger has been a member of the management board of the SENS Foundation, and is the Head of the Operations Division. In this position he co-ordinates the Technical Commission of SWICO/SENS in conjunction with Heinz Böni.

Public-private Partnership

The cantons of Aargau, Thurgau and Zurich have delegated the task of auditing companies recycling and dismantling electrical and electronic equipment to the take-back systems. This model makes sense for all involved parties. This not only provides relief for the cantons' stretched personnel resources, above all recycling and dismantling companies are grateful for not being audited by two different organisations for (largely) identical reasons. This form of collaboration therefore warrants a closer look.

To ensure that e-waste is disposed of in line with environmental requirements, the take-back systems enter into contracts with disposal and dismantling companies and collection points. These must be in possession of a cantonal license to accept and process electrical and electronic equipment in accordance with Article 8 of the Regulation on the Trade in Waste dated 22 June 2005 (VeVA)[1]. Therefore, the take-back systems assume the task, which in accordance with Article 5 of the Regulation on the Return, Take Back and Disposal of Electrical and Electronic Equipment dated 14 January 1998 (VREG)[2] was assigned to manufacturers, importers and the trade dealing in such equipment. The disposal is financed via a voluntary Advance Recycling Fee (ARF). This is not specified by law but is levied at the point of sale on new equipment.

Audit activity as the systems' core task

The systems organise and monitor the take-back and specialist disposal of the equipment. Their core tasks also include monitoring and auditing the disposal companies in line with statutory requirements and the systems' specific requirements for such tasks. The audits encompass the recycling companies and dismantling companies allocated to them. The take-back systems' independent auditor team audit the recycling partners at least once a year. The recycling partners are also responsible for the environmentally compatible operations of the dismantling companies contractually bound to them. The independent auditor team normally audit such dismantling companies every 2 years. Trained system employees conduct the audits at the collection points.

Public sector audit tasks

In accordance with Article 8 of VeVA, companies that accept equipment for disposal require a license issued by the canton in which the company is located. The canton specifies the type of disposal and the type and scope of reports about the disposed equipment. Where appropriate the licence also includes company-specific conditions to ensure the environmentally-compatible disposal of equipment as well as principles for conducting the recurring audits.

In accordance with Article 43 of the Swiss Environmental Protection Act (USG)[3], the enforcement agencies may delegate enforcement, particularly auditing and monitoring, to public bodies or private companies. Such outsourcing is justified if private organisations have at their disposal know-how that guarantees that the audits can be conducted properly. Since the systems' independent auditor team meet the necessary conditions, the cantons can dispense with their own checks and delegate the auditing of recycling partners and dismantling companies to the systems.

Assigning the audit activity

In this case the canton assigns to the take-back systems the duty to inspect recycling and dismantling companies licensed in accordance with Article 8 of VeVa and who are in contract with the take-back systems. The latter undertake to conduct the audits via their independent auditor team in accordance with the requirements specified as per agreement.

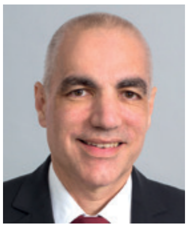
The systems organise the audits of the recycling and dismantling companies via their technical independent auditor team.

Complete transparency for the cantons

The systems inform the relevant cantonal departments at least four weeks before an audit, to give the departments the option of taking part. A report is drawn up on each audit and forwarded to the company and the commissioning official cantonal department. Reports list defects that have been specifically identified and state the arranged measures and dates. The canton is given an opportunity to comment.

Needless to say, sovereign measures may only be initiated by the respective official cantonal department. These also reserve the right to conduct official random checks at the companies subject to supervision, potentially issue orders regarding remedial actions, and bring charges against companies. The canton has, at all times, a right of access to the files insofar as the matter involves information affecting its sovereign tasks. The systems and their independent auditor team are required to maintain official secrecy, and comply with the data protection provisions that apply to the public sector.

The cantons that have signed the agreement specify verifiable performance and efficacy goals in conjunction with the systems. At least once a year, representatives of the official cantonal departments meet representatives of the systems to analyse the audit results as a whole and discuss potential adjustments to the audits.



Jean-Marc Hensch

Jean-Marc Hensch completed a university course as lic. iur. (Master of Law) at Zurich University, and passed the Higher Specialist Examination as a federally certified PR adviser. After two decades as an executive in the communications sector he assumed the management of the Swiss Natural Gas Association and also qualified as a gas safety officer. Today he is the Managing Director of Swico and Chairman of the Environmental Commission which is responsible for all activities performed by Swico Recycling. In his blog (jmhensch.wordpress.com) he deals, among other things, with current aspects of recycling waste electronic equipment.

Costs under control

Costs incurred by the independent auditor team for their company audits and the corresponding reporting are covered by the Advance Recycling Fee levied by the systems, provided the audits do not extend beyond the technical requirements specified by the SENS Foundation and Swico.

Additional expenses incurred by the canton for additionally commissioned audits are based on the respective, current hourly rates of KBOB[4]. The systems invoice the audited companies directly in accordance with such rates.

A win-win situation

Assigning the cantons' audit tasks to the systems has advantages for all involved parties. As a result, the companies subject to supervision are not audited several times for similar reasons. The cantons can make arrangements to honour their obligation to provide information on financially favourable terms without in any way compromising their sovereign rights. Small cantons, in particular, also benefit from the fact that the selected specialists who operate in the systems enjoy wider-ranging knowledge and have greater experience in this specific area. From the systems' viewpoint it would be highly desirable if additional cantons were to decide in favour of such co-operation.

1 http://www.admin.ch/ch/d/sr/c814_610.html

2 http://www.admin.ch/ch/d/sr/814_620/index.html

3 http://www.admin.ch/ch/d/sr/c814_01.html

4 Co-ordination conference of the building and property committees of the public building companies KBOB; http://www.bbl.admin.ch/kbob/

The Euronorm for e-waste disposal – a standard with its roots in Switzerland

At the beginning of March this year, a draft of the European CEN/CENELEC[5] was drawn up on the treatment of used electrical and electronic equipment. It is currently with the national standards organisations in the consultation stage. In the absence of fundamental objections, this draft will be submitted to the national commissions for authorisation in the middle of the year and, if accepted, pass into law in February 2014.

Norm with its roots in Switzerland

This is a milestone in the standardisation of waste electrical and electronic disposal with its roots in Switzerland. As early as the 1990s, the SENS Foundation and Swico began drawing up technical and organisational requirements for the disposal quality of e-waste as part of their contracts with recycling companies. The Swiss take-back systems improved their own standards in stages until ultimately the two standards were harmonised in 2009. An English translation was used as the first draft for the WEEELABEX Standard, the development of which commenced at the beginning of 2009. Similarly, Switzerland was the chief initiator of the WEELABEX project. The four-year project, which was co-financed by the EU Environmental Fund Life+, was aimed at developing and implementing a European standard. After more than two years on 1 April 2011, the 9th version was adopted at the general meeting of the WEEE Forum[6], the owner of the WEEELABEX Standard. The WEEE Forum has gained importance as a result of the adoption of this WEEELABEX standard. European manufacturers, recycling companies and their associations took note, and wanted to exert their influence and demonstrate their interest. For tactical reasons, the WEEE Forum therefore decided to launch the WEEELABEX Standard as a European standard, and two years ago incorporated it in the European Norm Organisation CEN/CENELEC.

History of standardisation and regulations

1998	First technical requirements in the Annex to the disposal contract with the partners that process and recycle equipment by order of the SENS Foundation
1998	The Swiss Executive Federal Council passes into law the Regulation on the Return, Take Back and Disposal of Electrical and Electronic Equipment (VREG)
2000	The Swiss Federal Office for the Environment issues a VREG implementation guideline in which fact sheets describe the current state of the art in disposing of electrical and electronic equipment
2003	The WEEE Directive becomes the first uniform EU regulation
2004	Review of the Swico processing guidelines
2005	The first major review of the SENS standard is undertaken in line with the new circumstances under the title «Easyrec»
2009	The SENS Foundation and Swico standards merge to form uniform technical requirements for treating electrical and electronic waste
2009	The WEEE Forum begins work on developing a private European norm. It is based on the English translation of the Swiss technical requirements
2011	The WEEE Forum becomes a member of the European Committee for Electrotechnical Standardization CENELEC, and makes arrangements to develop an official European norm based on WEEELABEX
2012	The first review of the WEEE directive from 2003 is passed into law by the EU Commission
2013	The European Committee for Electrotechnical Standardization CENELEC is officially commissioned by the EU Commission with the task of drawing up a comprehensive standard in line with the latest technological developments. It is set to acquire binding force for all EM Member States at the next review of the WEEE directive in 2016
2013	The general part of the CENELEC standard series reaches the consultation stage under the title WEEE Treatment Standard EN50XXX-1 before it is set to be voted on in the national norm commissions in autumn this year

Minor concept differences

The Swiss technical requirements in respect of the development of the WEEELABEX Standard have changed hugely in the period from 2009 to the present. The texts have been analysed, discussed and modified during dozens of working group meetings. Structural changes were needed due to regulations of the European Standardization Committee. In addition, direct references to conformity with the law are not permitted in European standards. Statutory provisions are not to be repeated or even modified in standards. Standards are to specify supplementary requirements for services and products and, above all, specify the methods and the procedure as to how such services are to be measured.

Europe - Switzerland comparison

Areas	EN 50xxx-1 WEEE treatment standard	Technical requirements SENS / Swico
Legal conformity	Recommendation only (CEN/CENELEC rules)	■ Obligation to provide evidence of compliance ■ Relevance assessment ■ Document registration obligation
Management obligations	■ In principle an environmental management system (certification not required) ■ Continual improvement	■ No explicit requirements ■ Responsibilities of company to be clearly specified
Monitoring of external further processing	■ In principle responsibility specified for all components up to the end-of-waste status	■ Responsibility specified in principle ■ Obligation to provide details of material flows ■ Simplified obligation to provide details in the case of metal fractions
Training	■ Differentiated duty to disclose according to type of component ■ General training obligations ■ Performance review ■ Aid availability ■ Occupational safety instructions	■ No general requirements ■ Explicitly worded for pollutant identification and removal
Mixing ban	Not available: treatment with other waste possible	Separate e-waste processing generally specified (exceptions possible)
Storage quantities limit	50 % annual capacity for complete units	< 20 % annual turnover for complete equipment (reporting obligation for exceptions)
Weather protection storage	Very vague principle that leaves a great deal unanswered	Obligation in principle, exceptions if proof is provided that discharge conforms to legal requirements
Containers	Decontamination obligation	None
Pollutant removal	Extremely detailed provisions in 2 Annexes	Simpler provisions, similar in relation to content
Checks on pollutant removal	Benchmarks from batch trials with plausibility determination for normal operations: batteries, capacitors and printed circuit boards	Benchmarks only for batteries and capacitors from annual material accounting
	Thresholds for RESH fraction	Thresholds for RESH fraction
Incineration obligation	Very vague provision with exceptions in regions in which waste incineration plant capacities are lacking	Restrictive wording including exports
R&R quotas	Batch principle: Figures from the WEEE directive	Batch principle: Figures from the WEEE directive
Recording obligations	Long list specifies little (annual mass balance)	Fewer obligations, but specified in greater detail (material accounting)

[5] CENELEC: European Committee for Electrotechnical Standardization, Brussels

[6] The WEEE Forum is the European Association of Collective Take Back Systems comprising 40 systems in 21 countries.
In Switzerland, SLRS, Swico and SENS are members.

Irrespective of these changes, the basic principles of the disposal services remain the same:

- The recycling company is to ensure that the companies that further process its components also adhere to the provisions of the standard. This monitoring obligation extends to recycling or the disposal of fractions.
- The legal requirements for the removal of pollutants are specified in greater detail and reviewed in terms of quantities using Benchmarks and pollutant thresholds in the components from the equipment processing.
- The recycling and recovery quotas specified in the European Directive are determined in a batch trial. Uniform requirements apply to such a batch trial and are based on the long-standing experience in Switzerland.

The objective of the standards is ultimately the same: minimising harmful effects on the environment and health, and maximising the creation of the highest quality secondary raw materials.

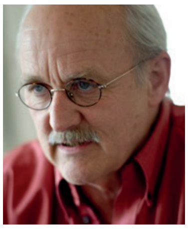
Significant detail differences

Pinpointing the differences between two standards with different structures is not as easy as it seems. A comparison between the draft for the CENELEC Standard and the Swiss technical requirements is outlined in the table. In the draft for the CENELEC Standard, the management and training obligations of those with responsibility in the recycling companies are more pronounced and formalised than in the Swiss requirements. While the mixed processing of electrical/electronic waste and other waste is tolerated in Europe, it is practically prohibited in Switzerland. Furthermore, the maximum storage quantities and the protection of stored equipment against adverse weather conditions are less restrictive in the European standard. By contrast, the quantitative benchmarks for the removal of pollutants from batteries and capacitors on printed circuit boards have been expanded. However, in view of the Swiss experience it is doubtful whether this is a feasible option. Ultimately, this standard reflects the European situation vis-à-vis waste disposal. The principle of the obligation to incinerate flammable waste will also be retained in Europe. However, the mere fact that many southern and eastern countries, but also France or England, have insufficient incineration capacity necessitates exemptions in the European standard.

WEEELABEX – Working Group on Standards Development 2010, supported by the EU Environmental Fund Life+

Standard to be legally binding

Although the stated differences in details may be individually relevant, there is an overwhelming case for the advantages of a well-conceived European standard with the right objectives. The EU Commission officially commissioned the European Committee for Electrotechnical Standardization CENELEC this year with the task of drawing up a standard for all equipment types and further processing technologies for electrical and electronic waste. This has led to a whole series of standards of which the first and most important is now in the consultation stage. It is envisaged that the first of this series be passed into law as early as the next review of the WEEE directive in 2016. If this comes to pass, the initiative and efforts undertaken by the SENS Foundation and Swico in the last 20 years will have had a direct impact on how European legislation is framed. Although Switzerland has not undertaken to implement EU law regarding waste, the Swiss take-back systems will implement the CENELEC norms. To date they have been hardly diluted during the course of the development. In addition, Europe's internal borders are increasingly opening, even for waste, giving rise to calls for equal conditions on both sides of the border.



Ueli Kasser

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

Is it worth extracting critical metals from electronic waste?

Electrical and electronic waste are secondary raw materials and therefore by definition significant for both society and the economy. Such waste has been collected and recycled for more than 15 years in Switzerland. More than 120,000 tonnes of e-waste are collected annually from which predominantly base and precious metals are recovered. Many rare or critical metals are lost in the treatment processes. The BAFU/Swico «e-Recmet» project aims to determine the technical and organisational preconditions that would be necessary to facilitate the recovery of critical metals from electronic waste in the future.

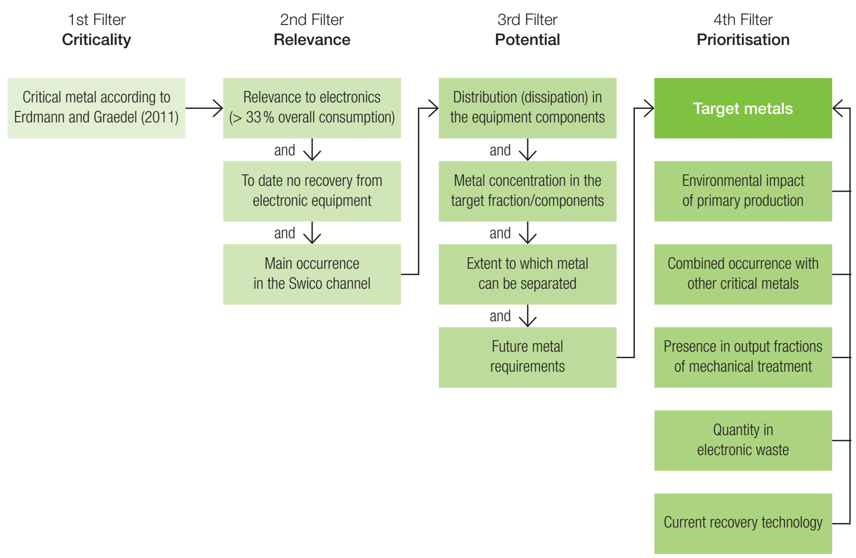
In addition to base metals such as lead, tin and aluminium, the electrical and electronic equipment we use daily contains a raft of rare metals that play a central role in the functionality of high-tech equipment. Besides precious metals such as gold, silver or palladium, these include less well-known elements such as indium, the rare earth metals or tantalum. Indium, for example, is required for the manufacture of transparent, conductive coatings in flat screen monitors. The rare earth metals neodymium, dysprosium and praseodymium are used for the manufacture of powerful neodymium-iron-boron permanent magnets in hard disks and optical drives. Tantalum is found in high-capacity mini capacitors, e.g. on printed circuit boards of mobile telephones. What all these metals have in common is the fact that they cannot be recovered using the present preparation and recovery processes. On the one hand this is because the process operations involved in the manual and mechanical processing are geared towards the removal of pollutants and the recovery of traditional materials such as aluminium, iron, copper or gold. On the other, although the price of these metals has increased sharply in the last few years, it is still too low and volatile to render the recovery interesting from an economical point of view. The future supply of these metals is considered critical, they are not renewable materials that would be withdrawn from future use without recovery, and significant amounts of the annual world production of these metals are used in electrical and electronic equipment. These facts call for a closer look to be taken at the potential of increased recovery of these metals.

It was precisely this reason which gave rise last year to the E-RECMET project, (Recycling of Critical Metals from Electronic Waste), which is financed by the technology development fund BAFU and by Swico. The project pursues two complementary approaches: on the one hand the question arises as to the preconditions that are necessary to facilitate the recovery of critical metals from a technical viewpoint, and on the other the requirements to be met by Swico Recycling's management system in respect of such recovery. Or in other words: can and should the recovery of critical metals be supported financially via the ARF, and what would that mean from an ecological viewpoint?

Screening critical metals in electronic waste

The E-RECMET project, which was launched in January 2013, is being implemented by Empa in conjunction with the Institute for Environmental and Process Technology UMTEC of the Rapperswil University and the engineering company Ernst Basler + Partner AG, Zurich and in co-operation with the Swico recycling companies. The first step of the project envisages taking a closer look at the situation involving critical metals in electronic waste. This is based on studies and investigations on the past and future mass flows of electrical and electronic equipment, and details of the composition of equipment. The project was never going to be able

Diagram 1: Selection procedures for the critical metals



to address the recovery of all critical metals. Therefore, the first step envisages a reduction to two critical metals. In that respect it is envisaged that the knowledge to be gained by way of the selection of the two metals from the following detailed investigations will be complementary.

Diagram 1 shows the procedure used for selecting the metals. If one bases the starting point on the critical metals in electronic waste and the so-called conflict metals[7] (gold, tantulum, tin und tungsten), these account for no less than 36 elements in our table of elements. If one investigates these 36 elements as to their relevance in Swico's mass flow, 13 elements remain. Of these, eight elements show increased potential for recovery: indium, ruthenium and yttrium as well as five metals from the group of rare earths, namely dysprosium, gadolinium, holmium, neodymium and praseodymium. The subsequent prioritisation of these eight metals means that indium and neodymium are the metals best suited for further investigation.

Indium and neodymium

Of the two elements proposed for further investigation, indium and neodymium, considerable quantities occur in Swico's quantity flow. According to the investigations conducted by the Oeko-Institut in Germany, a laptop, for example, contains about 2 g of neodymium. If one takes the approximate figure of 359,000 laptops disposed of in 2012, about 754 kg of neodymium can be recovered from this equipment category alone. Overall, the neodymium quantity would probably run to several tonnes. In the case of indium, approx. 0.7 g /m^2 are thought to be contained in a monitor surface, which in total produces more than 50 kg each year.

[7] Conflict metals are metals from conflict regions

Diagram 3: LCD panel with indium tin oxide

Further steps

The next part of the project involves a more detailed preparation of the two case studies - indium and neodymium. To that end, more detailed quantity forecasts will be made, a sampling and preparation concept drawn up for the chemical analyses. This work forms the basis on which to obtain more detailed quantities and composition details, and create a concept for the two case studies. In the second half of 2013 attempts will be made to process the metals. Samples of various fractions will be taken and analyzed for their indium and neodymium content.

Subsequent investigations will compare the environmental impact of the recovery of neodymium and indium from e-waste with the effects from extracting these metals from mining, e.g. in China.

From an economic viewpoint, interest ultimately turns to the question of what type of increase in the Advance Recycling Fee (ARF) would be required to make the recovery of indium and neodymium financially viable.

The project will be completed in autumn 2014. By then Swico will have the basis for answering the question as to whether the recovery of critical metals from e-waste is technically and economically feasible, and if necessary, be in a position to proceed by 2015.

Heinz Böni

After graduating as an agricultural engineer at ETH Zurich, and a post-graduate course in domestic waster supply construction and water conservation (NDS/EAWAG), Heinz Böni worked as a research associate at EAWAG Dübendorf. After holding the position of project manager at the ORL Institute of ETH Zurich and a stint at UNICEF in Nepal, Heinz Böni took up the position of Managing Director of Büro für Kies+Abfall AG in St. Gallen. After that he was a co-owner and managing director of EcoPartner GmbH St. Gallen for several years. He has been at Empa since 2001, where he is head of the CARE (Critical Materials and Resource Efficiency) group and interim head of the Technology and Society department. From 2009 he has held the position of Head of the Technical Audit Department of Swico Recycling, and has been an audit expert for Swico and the SENS Foundation since 2007.

Patrick Wäger

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

Further increase in processed quantities

Compared with the previous year, the quantity of recycled e-waste has increased by almost 10 %. The high quality of recycling has again led to an e-waste recovery quota of about 75 %.

In 2012 the quantity of e-waste processed by the SENS and Swico recycling companies increased compared with the previous year by more than 10,000 tonnes to a total of 129,100 tonnes (Table 1, Diagram 1). As in the previous year, appliances not listed in the Regulation on the Return, Take Back and Disposal of Electrical and Electronic Equipment (VREG) accounts for the largest increase (16 %). This is equipment used in industry, trade or in hospitals. The sharp increase is attributable to industrial orders settled directly by the SENS and Swico recycling companies and partners in industry. Similarly, Small electronic appliances (household appliances) increased sharply (15 %). Electronic appliances and large electrical appliances processing was either flat or even dropped last year. This year it increased by 8 % and 9 % respectively. At 4 %, the quantity of recycled refrigeration, freezing, air-conditioning and compressor appliances showed the smallest increase. Only the quantity of lighting equipment showed an actual decrease. This was attributable to the technical challenges of processing energy-saving lamps. These lamps were not processed in some companies, but rather stored awaiting introduction of new treatment processes.

Raw material recovery and pollutant removal

During the recycling process the various material and pollutant fractions are separated both manually and mechanically. Manual activities play a key role in the sorting and removal of particularly valuable equipment parts and components as well as those that contain pollutants. Table 2 shows the precise composition of the processed fractions totalling 129,100 tonnes. The fractions are largely made up of metals (55 %) and to a lesser degree plastics (14 %), a mix of metals and plastics (12 %) and cathode ray tubes (CRTs) from old monitors and TVs (9 %). Printed circuit boards (PCB) (containing particularly valuable materials) and the pollutants merely account for 1% to 2 % of the entire processed quantity. Quantities of individual material fractions have changed only slightly compared

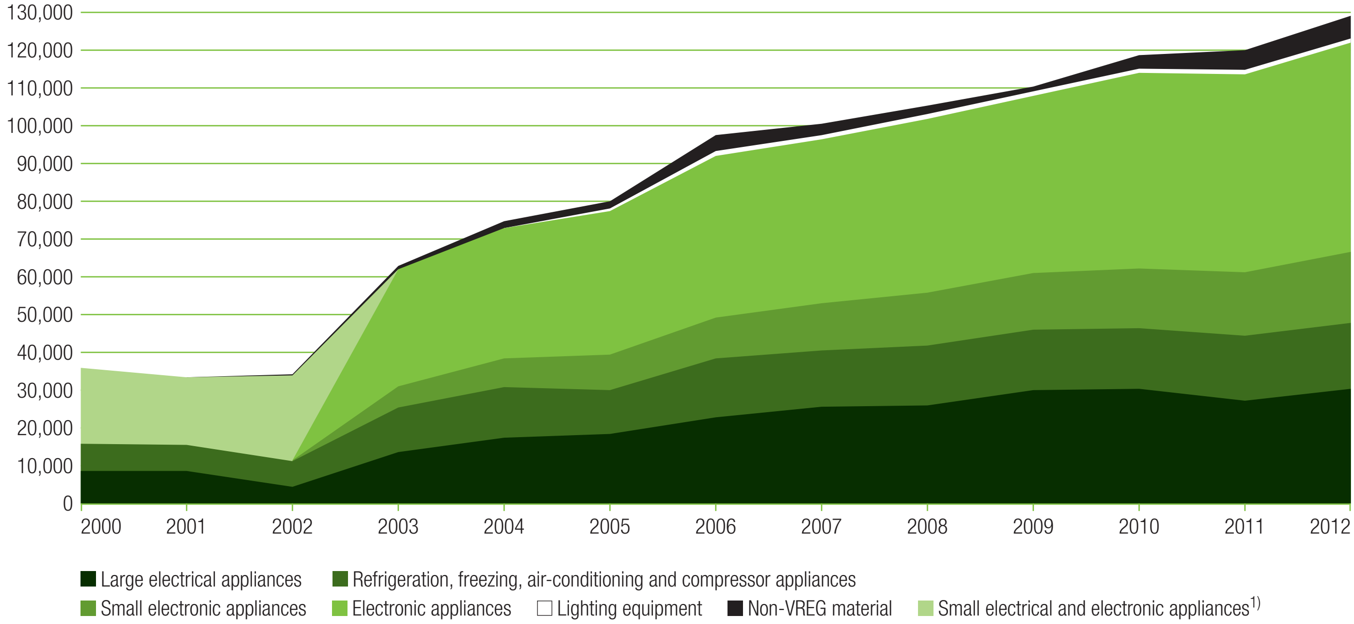
Table 1: Total processed electrical and electronic equipment in Switzerland in tonnes from the material flow survey

Year	Large electrical appliances	Refrigeration, freezing, air-conditioning and compressor appliances	Small electronic appliances	Electronic appliances	Lighting equipment	Non-VREG material	Total tonnes/ year
2000	9,600	6,900	Total 19,800				36,300
2001	9,600	6,700	Total 17,500				33,800
2002	5,600	6,400	Total 22,300			300	34,600
2003	14,600	11,600	5,400	30,200		800	62,600
2004	18,100	13,100	7,500	33,700		1,800	74,200
2005	19,100	11,400	9,300	37,200	420[1)]	1,900	79,320
2006	23,400	15,300[2)]	10,700	41,800	1,100	4,200	96,500[2)]
2007	26,100	14,500	12,300	42,500	1,110	2,900	99,410
2008	26,800	15,100	13,800	45,000	1,130	2,300	104,130
2009	30,400	15,300	14,900	47,300	1,100	1,200	110,200
2010	30,700	15,900	15,400	50,700	1,130	3,500	117,400
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
Changes compared with the previous year	**9%**	**4%**	**15%**	**8%**	**-13%**	**16%**	**9%**

1) In 2005 only five months are recorded since introduction of the Advance Recycling Fee on 01.08.05.

2) In 2006,1,300 tonnes of trade equipment were included in the statistical survey of cooling equipment in addition to domestic equipment.

Diagram 1: Growth of processed equipment quantities in Switzerland in tonnes



1) Up to 2002 small electrical and electronic appliances was recorded jointly

to 2011. The overall quantity of pollutants dropped compared with the previous year. This shows that the pollutant content in e-waste is falling as a whole. As in previous years, the quantity of asbestos disposed of also increased. This underlines the continuous improvement among recycling companies in sorting out equipment containing asbestos. Batteries, CFCs and oils also increased slightly. The apparent low quantity of pollutants (about 1,100 tonnes) in e-waste should not be allowed to hide the fact that in addition to raw material recovery, pollutant removal ranks among the most important tasks performed by a SENS-Swico recycling company.

High recycling quota maintained

Again in 2012 about 75 % of materials recovered from e-waste were subject to further recycling. In that respect, the various metal fractions forwarded by the e-waste recycling companies directly to the metal trade and smelting plants without additional preparation accounted for the largest recycled fraction. The share of recycled plastics increased in the last few years, and in 2012 was about 75 %. High-quality mixtures of metal and plastics are separated abroad using complex preparation processes to create pure metal and plastics fractions. This enables metals, and in some cases, plastics to be recycled. Based on the available data, effective recycling quota cannot be determined because the metal and plastic ratio differ considerably depending on the initial treatment process. Glass fractions (monitor glass, flat glass and recycling glass from lamps) as well as cables, printed circuit boards and batteries are recycled.

Diagram 2: Composition of created fractions in % in 2012

Pollutants that in total only account for 1% of the created fractions are stated separately.

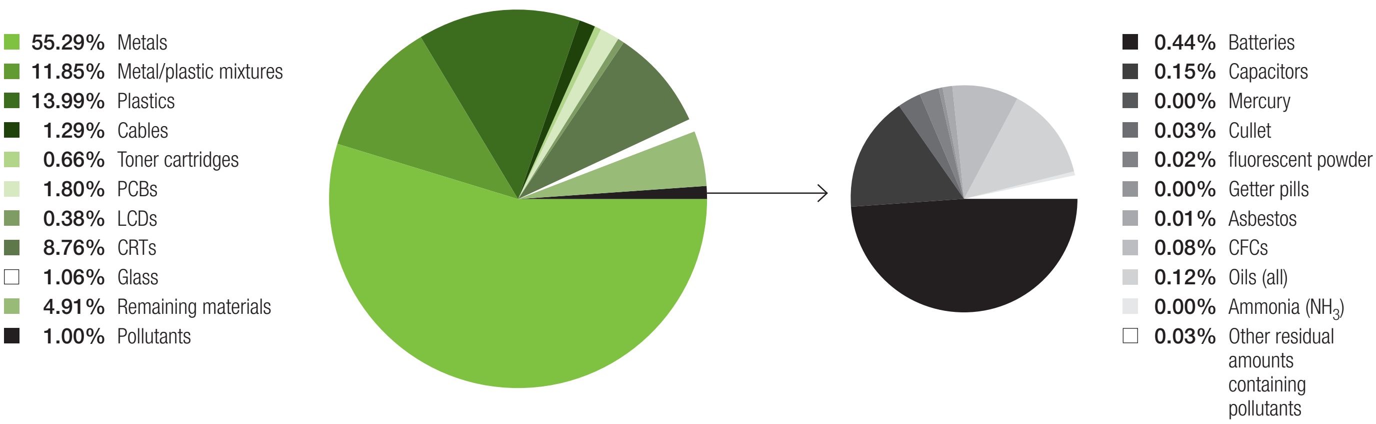


Table 2: Collected Swico quantities and composition according to equipment type

	Quantity[3] (in 000s)	Average weight (kg)	Metals (tonnes)	Plastics (tonnes)	Metal-plastic mixtures (tonnes)	Cables (tonnes)	glass and/or LCD modules (tonnes)	Printed circuit boards (tonnes)	Pollutants (tonnes)	Others[4] (tonnes)	Total (tonnes)	Increase/reduction compared with 2011
PC monitors CRT	302	18.17	805	1,092	521	141	2,399	503	0,30	25	**5,486**	4%
PC monitors LCD	406	6.23	1,080	604	-	10	636	176	8.2	12	**2,525**	8%
PCs/servers	338	15.06	4,192	293	14	156	-	424	16	-	**5,096**	-6%
Laptops	359	3.55	387	360	130	6,5	112	186	88	5.3	**1,275**	33%
Printers	492	10.63	1,855	2,815	322	29	36	92	1.6	85	**5,235**	12%
Large copiers/large equipment	46	1,212.00	3,075	252	1,983	98	4.3	54	47	108	**5,621**	2%
IT mixed[1]	398	10.51	2,281	174	1,504	73	1.5	37	34	76	**4,181**	3%
CRT TVs	575	28.84	1,633	3,388	551	58	10,713	203	16	9	**16,570**	-2%
LCD TVs	55	35.63	812	292	-	39	506	240	18	68	**1.976**	31%
CE mixed[2]	2,384	4.51	5,866	447	3,869	188	3.8	96	88	195	**10,754**	5%
Telephone mobile	498	0.14	11	25	-	-	3.7	16	14	-	**70**	10%
Telephone rest	1,081	2.13	1,255	96	827	40	0.8	21	19	42	**2,300**	3%
Photos/videos	284	0.49	75	5.8	50	2.4	0,048	1.2	1.1	2.5	**138**	18%
Dental											**67**	6%
Total in tonnes			**23,327**	**9844**	**9771**	**842**	**14,417**	**2048**	**351**	**627**	**61,295**	**3%**
Total in percent			**38.1%**	**16.1%**	**15.9%**	**1.4%**	**23.5%**	**3.3%**	**0.6%**	**1.0%**		

1) IT equipment, mixed, without monitors, PCs/servers, laptops, printers, large-scale copiers/large-scale equipment
2) Consumer electronics, mixed, without TVs
3) Projection
4) Packaging and other waste, toner cartridges

Detailed survey on electronic equipment

Thanks to the detailed market basket analysis and targeted processing trials involving certain product groups, Swico is able to itemise the take-back quantities and composition of electronic equipment in even greater detail. In 2012, Swico took back 61,295 tonnes of electronic equipment, 3 % more than in the previous year. Laptops and LCD TVs accounted for the highest increase in take-back quantities at 30 % each, reflecting the trend in LCD TVs that had already been established in the last few years. Furthermore, 12% more printers were taken back than in the previous year. The increase in Smartphone sales in 2012 translated into an increase of 10 % in recycled mobile phones. Although new CRT equipment has not been sold for several years, returned quantities have remained constant over the last few years. On the one hand, this may be attributable to the long useful life of cathode ray tube screens. Alternatively, it is likely that many such old devices have been stored without being used, and take longer to find their way into the recycling process.

The composition is determined via the processing trials conducted by the Swiss recycling companies and supported by Empa. This involves collecting and processing a predetermined quantity of equipment and documenting the resulting fractions. The composition differs considerably from product group to product group. The processing trials are therefore a source of of interesting and additional key information. For example, PCs and servers have the highest metal content, printers contain a lot of plastic, CRT monitors and TVs are largely made up of glass, while mobile telephones have the largest content of printed circuit boards containing precious metals (gold, silver and palladium).

Esther Müller

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

Geri Hug

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

Market saturation for the recycling of cooling appliances yet to be reached

The number of processed cooling appliances continues to rise. At 17,500 tonnes, a new peak was reached in 2012 (over 4% increase). The four available plants processed in total more than one third of a million appliances at step 1 (extraction of refrigerants from compressors) and step 2 (extraction of blowing agents from the insulation foam). As in previous years, a small proportion of all appliances was recycled at a foreign plant (3 %).

Relevance of treatment of cooling devices

The ambitious goal of 90 % recovery of both refrigerants and blowing agents is significant in two respects: on the one hand, the CFCs contained in compressors and PU foam insulation need to be removed from the recycling process and destroyed under controlled conditions due to their detrimental effects on the ozone layer. On the other hand, these substances have a global warming potential that exceeds the one of CO_2 by approximately one thousand to ten thousand fold. Important aspects of environmental protection are therefore the recovery and subsequent high-temperature incineration of the refrigerants and blowing agents and their conversion into far less climate-changing CO_2 and water, acids or salts.

Substitution of refrigerants and blowing agents since 1994

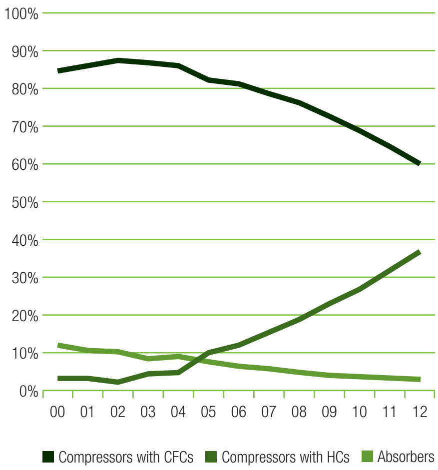
Environmental and climate protection measures have also been adopted for the manufacture of new equipment since the middle of the 1990s. The gradual substitution of the refrigerant CFC-12 by the ozone-friendly, but nevertheless climate-changing FC-134a, to hydrocarbon (HC) isobutane, which does not pose problems in either respect, was implemented as part of an international agreements (Vienna Convention and Montreal Protocol). The change in blowing agents was implemented sooner and quicker: in that respect, CFC-11 was directly substituted by the completely ozone-friendly hydrocarbon cyclopentane, which additionally has a practically negligible global warming potential.

Implementation of the substitution measures at different times in respect of the manufacture of cooling appliances also applies to recycling: at step 1, the proportion of treated HC-operated compressors has been steadily increasing since 2003. At step 2, this increase among HC-foamed housings commenced as early as 2000.

Drop in CFC compressors

While 65 % of the cooling systems recycled in the survey year of 2011 were of the CFC type, the figure in 2012 was still 60 %. By analogy, in the same period the proportion of HC-compressors increased from 31 % to 37 %. The absorber systems containing ammonia dropped slightly from 4% to 3 %. A balance between CFC and HC-compressors will likely be reached in a period of two to four years –> Diagram 1

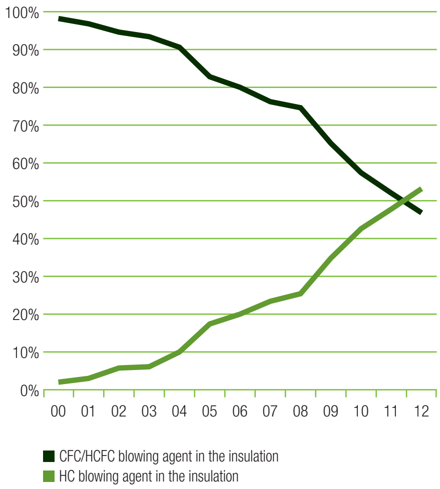
Diagram 1: Development of appliance types treated at step 1 (compressors containing CFCs and HCs,and absorber systems containing ammonia)



More HC-foamed cooling equipment for first time

There is a steady decline in CFC-foamed appliance housings. In 2012, the proportion dropped below the 50 percent mark for the first time to 47 %, therefore proving the accuracy of last year's trend forecast. At 53 %, the HC- (cyclopentane) housings for the first time account for the majority of all treated equipment. –> Diagram 2.

Diagram 2: Development of appliance types treated at step 2 (CFC and HC-foamed PU insulation)



Minor reductions in recovered quantities

The quantity of recovered refrigerant mixtures varied only slightly in the last few years with an average content of 100 g per compressor. In 2012, 95 g of refrigerants were extracted from each cooling device. The slight reduction could reflect the specific drop in refrigerant quantities (HC compressors contain significantly less) because the quantity of cooling devices treated at step 1 remained practically unchanged compared with the previous year. This assumption may only be corroborated in the coming years. Furthermore, at 214 g oil for each compressor, the efficiency indicator for the suction performance has remained almost constant –> Diagram 3.

A similar picture emerges with regard to recovering blowing agent mixtures. However, contrary to the development of the refrigerant curve, for which meaningful time forecasts cannot be made, over the past twelve years a clear downward trend has been observed in the proportion of blowing agent recovered from each kilogram of PU foam insulation. While in 2011 the reference figure was 60 g per kilogram PU, in 2012 a survey of all recyclers produced a figure of 58 g per kilogram PU (Diagram 4). In this case, the reduction is attributable to the lower specific weight of cyclopentane compared with CFC-11. The downward trend will continue, and the minimum recovery figure will stabilise at 40 g to 45 g of blowing agent at some point in the future. This forecast is based on the assumption that the specific quantity of cyclopentane per kilogram of PU foam will be about 45 g at the end of the life cycle, and that most of the housings being treated will almost only be of the cyclopentane type.

Diagram 3: Reclaimed CFCs/HCs and oil from the cooling cycle (Step 1)

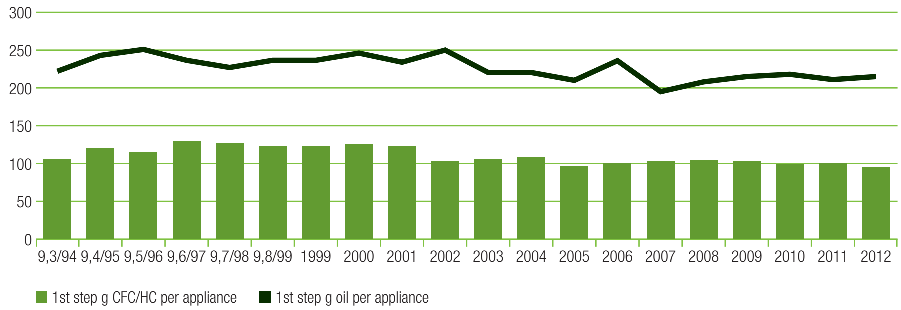
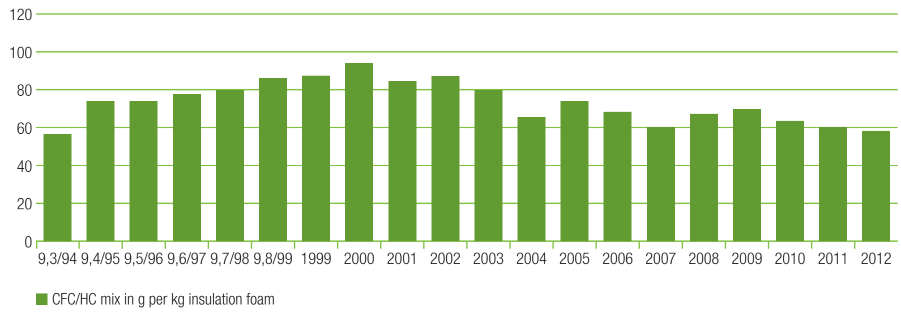


Diagram 4: Reclaimed CFCs/HCs from PU insulation foam (Step 2)



Geri Hug

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Niklaus Renner

Niklaus Renner studied environmental sciences at ETH Zurich. He has been a research associate at Roos+Partner AG, Lucerne, since 2007. As part of various studies, he deals with the environmental compatibility of scrap metal and e-waste recycling. Among other things he was involved in conducting a survey on the mercury levels of fractions of processed lamps for the SENS and SLRS Foundations. In addition, Niklaus Renner's tasks include monitoring environmental law, applying the legal compliance tool LCS.pro and internal environmental conformity audits. Audits for the environmental inspectorate AGVS (car trade association), and from 2013 accompanying soil protection measures for construction projects round off his profile.

Recycling toner waste

Although the recycling of imaging accessories such as toner cartridges is desirable, up to now it has repeatedly failed due to the lack of a suitable technology. No system has been able to deal with the mixture of plastics, metals and toner dust, still less provide a solution in an interesting economic setting. Although there are a number of solutions worldwide that partially recycle metals or recover minor quantities of plastic, to date no system has been able to extensively recycle the entire product. In April 2011 Swico commissioned a project team made up of four experienced specialists with the task of finding new recycling methods for toner cartridges.

Starting situation

Swico Recycling recycles about 62,000 tonnes of electronic waste annually from the areas Office, Dental Trade, Graphics Industry, Informatics, Measurement and Medical Equipment, Security Technology, Telecommunications, Consumer Electronics, Accessories and Consumables. This quantity includes imaging accessories. A small part of the total amount finds its way into refills, where cartridges are refilled and reintroduced to the market. However, the lion's share of cartridges is disposed of in waste incineration plants (WIPs).

This solution is unsatisfactory for all involved parties. Waste incineration plants are increasingly refusing to accept such waste because the residual toner can cause dust explosions or have a detrimental effect on the filter systems. To counter the dust emissions, a so-called "baking process" has been developed in which the cartridges are heated in an oven until the toner powder polymerises and after cooling solidifies to form a plastic cake. Mixing with domestic refuse is another option. In the case of a five percent metered addition, the cartridges disappear in the remaining material, and no longer have a detrimental effect on the process in the waste incineration plant.

In the waste incineration plant the plastic burns completely, only the metals are partially recovered from the slag. This thermal recovery creates energy, i.e. heat, steam and electricity, but the plastics are completely lost. Furthermore, incinerating one tonne of toner cartridges produces about two and a half tonnes of CO_2. In addition to the high cost, this type of recovery is therefore not resource-efficient.

New methods

About 1,800 tonnes of imaging accessories are produced in Switzerland each year that require professional and sustainable recycling: toner cartridges, toner bottles, toner containers with residual toner and packaging material. The recycling plays a part in resource efficiency in that the materials are recovered, i.e. are fed back into the materials cycle. However, certain principles must be respected: toner cartridges are accessory parts made up of various components normally comprising several plastics applications, composite materials, metals and the toner powder. The latter consists of plastic powder with additives.

To be recycled the cartridges need to be broken down to the highest possible degree of purity. The higher the purity of each fraction, the higher its value. The goal is to recover individual fractions for new products, ideally for the construction of new cartridges.

Processing trials

How can toner cartridges be processed so that the material can be as thoroughly separated as possible but is not broken down into pieces that are too fine? And how can the toner powder be removed? A plant should be capable of being operated efficiently, i.e. in automatic mode and profitably. Several steps are required to answer this question: evaluation of existing data, representative batch trials, manual dismantling, mechanical processing, laboratory trials and analyses, matching of collected data and, of course, incorporating expert experience.

Consumers frequently hand in the end-of-life cartridges in the original packaging. Of the 1,800 tonnes per year, the packaging accounts for about 300 tonnes, i.e. a considerable proportion.

The material question needs to be clarified as a first step. As you would expect, toner cartridges and containers/bottles with residual toner are extremely complex products:

- Cartridges are made up of 30 to 40 different metals and plastics
- Toner powder is made up of up to 40 different substances
- Packaging is made up of cardboard and up to five plastics

Manual dismantling

The dismantling of cartridges by hand conserves materials, but is not very efficient. The individual components are effectively dismantled through disassembly and remain whole. Materials are separated based on their quality and material identification. The dust emission is moderate, and can be solved with suitable means. Interesting options present themselves, primarily in the separation of plastics. However, the material identification on the components often differs from the actual material quality. This indicates that raw materials other than those stated are used in production. This phenomenon has been known for some time in the electronics industry.

Mechanical processing

More than 600 workers would be required to manually dismantle all toner cartridges. However, in practice that is completely unrealistic. Technical support is therefore required to perform this task.

In the project stage comprehensive infrastructure is necessary to conduct major trials under conditions as far as possible replicating real life. System builders in Europe operate so-called Technika (machine parks) to conduct processing trials with real materials under real conditions. In this case, know-how drawn from six Technikum trials was used as the basis for the subsequent process development.

Toner cartridges are mechanically processed in various steps: first of all the cartridges need to be crushed and broken down using a shredder to create metal and plastic parts. Then the released toner dust needs to be collected and separated or removed from the crushed parts. Finally, the cleaned metal/plastic mixture undergoes a sorting process, and the individual fractions and semi-finished products are fed back into the production cycle.

Up to now there is no system on the market that can perform all these processing stages. That is why it is necessary to establish which system components achieve the best results in the individual partial processes or processing steps. This step-by-step process is the way to create a new toner recycling system.

Dry crushing

Crushing cartridges in a shredder works perfectly. However, irrespective of the air extraction and filter systems (air classifier), dust emissions are high. mixture of toner dust oxygen and air reaches a combustible composition, a static charge or another ignition source is sufficient to create an explosion. This represents a considerable danger and several accidents have resulted in fatalities. For safety reasons dry crushing must therefore contain an inerting function (nitrogen) in addition to the air extraction. Despite these measures it is almost impossible to prevent dust carriage. Residual amounts of toner dust as a result of static charges or magnetic parts cannot be avoided. However, the resulting metal-plastic mixture, which is quite pure, can be easily sorted in a separation system.

Wet crushing

In the case of wet crushing, the shredder room is filled with water. An added wetting agent breaks the surface tension of the water and binds the toner dust. This eliminates the risk of an explosion at the very start of the process, and through the subsequent rinsing the metal-plastic mixture is completely clean.

Thanks to further mechanical processing steps, the material is dried by vibratory abrasion. A two-stage filter system cleans the water in an internal circuit. The precipitated toner dust still contains residual moisture, and is thermally recovered.

Separating

The materials are separated following crushing and cleaning. Various technologies are used at this stage: FE separator, near infra-red and eddy current systems. This produces pure FE and NE metals as well as a black and coloured plastic fraction. All fractions are already marketable in this form.

Preparing plastics

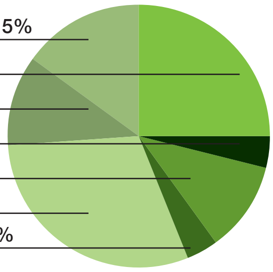
The plastics can be further processed. The float-sink and electrostatic separation processes produce grades of plastic with a 98% degree of purity. These can be incorporated directly in new products as grinding stock or regranulate. Extrusion trials at the Institute for Material Technology and Plastics Processing of the HSR Hochschule für Technik Rapperswil have confirmed the excellent quality of the material.

Fraction / Survey	Batch 1	Batch 2	Batch 3	Batch 4	Average
FE	22 %	30 %	41 %	29 %	31 %
NE	16 %	8 %	5 %	11 %	10 %
Plastics	47 %	45 %	46 %	38 %	44 %
Powder, light fractions	15 %	17 %	8 %	22 %	15 %

Material mix

The quality of the output fractions (metals and plastics) is primarily conditional on input material. The material may vary considerably depending on the product and residual toner content. Various batches are therefore processed using different methods to achieve the widest possible range in the material mix.

Detailed material mix



System implementation

The evaluation of all trial series and material analyses is followed by the process development. Four steps are required for the reuse of materials recovered from toner cartridges.

Step 1	Step 2	Step 3	Step 4
Delivery Unpack Triage	Crushing Cleaning	Separating	Processing

Step 1 involves the delivery and unpacking of the cartridges. There is an optional cartridge triage process prior to crushing. Cardboard and plastic packaging is pressed into balls or the EPS is compressed.

For step 2, which involves the crushing and cleaning of the input material, there are two possible options: dry or wet processing. After considering all advantages and disadvantages, wet crushing is judged to be the best option. Although the water preparation is complex, arguments such as operating safety (no risk of explosion), no dust carriage and cleaner fractions lead to a decision in favour of wet preparation.

Marketable metal-plastic fractions are produced already after the second processing step. Steps 3 and 4 can – depending on the quantities – be outsourced. Step 4 consists of the detailed separation and processing of the plastics to create grinding stock or regranulate.

The system costs in relation to professional, mechanical wet processing for processing steps one to three are about CHF 1.5 million. In Switzerland, with an annual quantity of 1,800 tonnes of toner cartridges and packaging, the economic and sustainable recovery of materials is only feasible if there is a single centrally operated system, preferably to receive all recycled cartridges.

The design is so far advanced that construction drawings for the plant have been prepared, specific locations have been evaluated and proposals have been put forward in a business plan for the operational organisation and processes.

Know-how

The reuse of materials recovered from toner cartridges is technically feasible, and the corresponding plant technology is available. The ecological advantages of recycling over incineration are undisputed. Both metal and plastic are recycled. Solely the toner powder cannot be recycled. As long as excessively high heavy metal concentration levels prevent the recovery of materials, they will continue to end up in waste incineration plants where at least the energy is used.

Revenue can be generated from recovering materials based on the assumption that one tonne of toner cartridge waste costs more than CHF 400 to incinerate. Under these conditions a system such as this could be operated at a profit.

Andreas Tonner

Following commercial training as a public administrator and subsequent higher professional training, Andreas Tonner worked for eight years in various administrative positions. In 1995 he moved to the waste disposal industry where he worked in the management of Tonner-Altstoff AG, Sereda AG and Texta AG, holding various administrative positions up until 2007. In 2008 he founded the company Recycling-Coach GmbH, which advises and coaches companies, associations and public entities. In 2010, Andreas Tonner founded the company Oekotech Reco AG, which focuses on material cost optimisation in waste disposal and raw materials marketing.

Ruedi Hafner

Following his training as a car mechanic, Ruedi Hafner completed further training as a construction plant mechanic, and worked in that role for several years. Seeking a new challenge, he subsequently completed additional training at Bucher Kältering becoming a refrigeration fitter, and after further training, a refrigeration technician. In 1976 he moved to the waste trade sector, working as a demolition manager at the company Metheil AG for ten years. In 1986, in conjunction with two partners, he established the company Immark AG, where he worked as technical director up until 2008. From 2008, Ruedi Hafner has been the managing director of the company Hareca GmbH, which advises companies in the recycling sector at home and abroad.

Mercury from energy-saving lamps

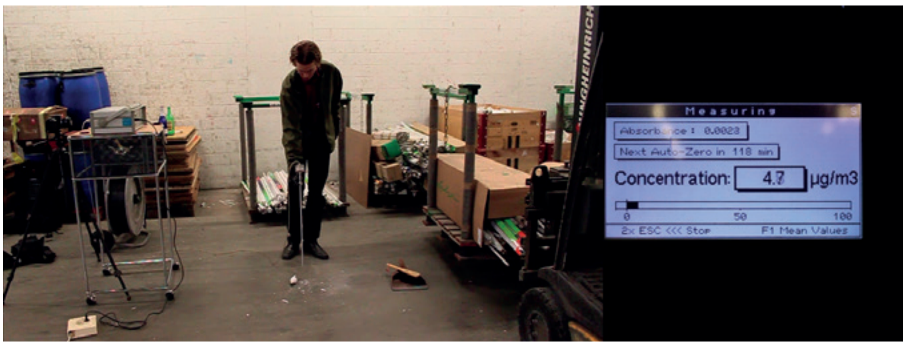
From an object of fascination to a banned substance

When the Caliph of Cordoba arranged to have a new palace built in 1,000 CE, it is alleged a pool filled with mercury (Hg) in the centre of the Golden Salon enchanted the visitors with its play of light. The mercury fountain by Alexander Calde could be admired at the 1937 World Fair in Paris. Today, it is exhibited at the Miro Museum in Barcelona - albeit behind glass. Paracelsus, the much-quoted discoverer of the correlation between dose and poisonous effect, recommended the internal application of mercury for medicinal purposes. Tragically, Paracelsus identified the correlation between dose and poison, but succumbed himself to mercury poisoning. Up until a few years ago, mercury was used as amalgam for tooth fillings and as a disinfectant (e.g. in Vita Merfen ointment up to the 1990s). Today, it is largely banned in open and closed applications. Energy-saving lamps, which work on the principle of discharging gas, are exempted. The function is based on stimulating the electrons in the mercury atoms, which emit ultraviolet radiation when rebounding to the non-stimulated level. The ultraviolet radiation is converted into visible light by the fluorescent powder on the glass surface.

Measurements in shopping malls and distribution centres

When energy-saving lamps (ESLs) break, elemental mercury is released as vapour. Depending on their age, energy-saving lamps may contain 2-20 mg Hg. This poses the question of whether or not the mercury poses a risk to health if the mercury vapour is inhaled. As part of a measurement concept various potentially critical situations in a major distribution centre were surveyed under realistic conditions. They included consumers throwing energy-saving lamps into the collection containers, lamps falling on the floor and breaking, during storage and while handling the containers. The measurements were made using an ongoing measuring device, and the display of mercury concentration levels was filmed in tandem so that the concentration level could be read simultaneously (see picture).

The continuous measurement produces a far more detailed picture of the correlations between the location, time and concentration level than with selective individual measurements. When ESLs break on the floor, the peak concentration levels are to be found directly above the floor. The figures for various situations are given in Table 1. The concentration level of mercury in the air drops sharply with an increase in the height at which measurements are taken. At head height, measurements ranged from merely a slight increase to no increase at all. The difference between the energy-saving lamps and the standard fluorescent tubes is significant. When fluorescent tubes break, the occupational exposure limit (OEL) is exceeded for a short period. In all other measured situations, either no increase or a very small increase in the mercury concentration levels was measured. In all measured rooms in the sales and distribution centres, the background concentration levels were less than 0.1 µg/m³ Hg. In any case the mercury released when lamps are broken is very quickly diluted by the air change to non-measurable concentration levels below the detection limit.



Measurement of mercury concentration levels after breakage of an energy-saving lamp

Table 1: Measured Hg concentration levels in various situations during the collection and return of ESLs and rod-shaped FLs

Measurement situation	Number of events	Peak value [µg/m³]	Average value [µg/m³]	Exposure period [s]
1: Breakage of ESL on the floor with subsequent wipe-up	4	2 97 46 33	0.5 15 6 9	90 100 90 90
2: Breakage of FL tubes on floor from height of 36 cm with subsequent wipe up	1	268	76	100
3: ESL thrown into collection point without damage	1	< 0.1	< 0.1	Not relevant
4: ESL thrown into collection point damaged	1	34	9	50
5: Interim storage in distribution centre upon delivery	2	Not relevant	8 5	Depending on work segment several minutes
6: Storage in transport container in distribution centre	3	Not relevant	1 2 6	Several minutes
7: Handling of lamps in distribution centre	1	Not relevant	< 0.1	Depending on work segment several minutes

Table 2: Dose of an event proportional to the background level for each year and an OEL peak

Quantified situations according to Table 1	Maximum absorbed Hg dose [µg]	% of urban background level per year	% of an OEL peak
1: Breakage of ESL on the floor with subsequent wipe up	0.4	0.5 %	0.4 %
2: Breakage of FL tubes on floor from height of 36 cm with subsequent wipe up	2.0	2.4 %	2.1 %
3: ESL thrown into collection point without damage	< 0.001	< 0.002 %	< 0.001 %
4: ESL thrown into collection point damaged	0.1	0.1%	0.1 %
5: Interim storage in distribution centre upon delivery: 30 minutes' work on the pallet	3.7	4.5 %	3.9 %
6: Storage in transport container in distribution centre: 30 minutes' work on the pallet	3	3.5 %	3.1 %
7: Handling of lamps in distribution centre	< 0.05	< 0.06 %	< 0.1 %

Insignificant mercury risk

To assess the risk, the maximum absorbed mercury dose of the respective situation was compared with the background level and the maximum figures in relation to occupational hygiene (Table 2). Conservative assumptions were made in that respect. In particular, mercury concentrations in the vicinity of the broken tubes were used for calculation purposes. For all events and work procedures in the collection points and distribution centre, the maximum inhalable mercury quantities are 20 to 1,000 times less than the quantities absorbed annually from the background concentration levels in the neighbourhood. A comparison of the occupational exposure with a brief peak that is just permitted in accordance with the OEL list shows that the absorbed mercury quantities are well below the permitted maximum levels. The mercury from a broken energy-saving lamp and the handling of collection containers during the take-back of energy-saving lamps do not pose any health risks. The mercury exposure from amalgam fillings that have not been removed, or the consumption of sea fish, is far higher.

Even if the measurements clearly show that breaking a single energy-saving lamp or fluorescent tube does not pose a risk, during the professional handling of lamps situations may arise that call for measures to protect employees' health. If large quantities of lamps are broken simultaneously, or if a closed container with many broken lamps is opened, the short-term OELs can be exceeded. Such cases necessitate the immediate ventilation of the room, and all employees should leave the room until it has been thoroughly aired.

Environmental impact through recycling

It is possible to assess the level of mercury load in Switzerland using the existing statistical data and a comprehensive study of mercury retention from fluorescent tubes in Swiss and foreign recycling companies.[11] The load comprise the mercury quantity contained in all the lamps collected in Switzerland in one year. Part of it ends up in the environment during collection and transport as a result of breakage. Another part reaches the environment as a result of unavoidable emissions during recycling process itself. Table 3 shows the estimated figures of individual lamp types.

A breakage rate of 5 % (fluorescent lamp tubes) or 7 % (energy-saving lamps) was assumed in respect of the process of handing in tubes to recycling companies to assess the emissions. In the case of lamps that remained intact when handed into recycling companies, it was assumed that 90 % of the input mercury was retained in the corresponding systems. The remaining 10 % are released into the environment during processing and storage and as residual content in the re-usable fractions of glass and metals. These figures emanate from a comprehensive measurement analysis in Swiss recycling companies[14].

Mercury emissions from the disposal of lamps are insignificant when compared to overall emissions (Table 3). The primary source of mercury emissions in Switzerland is steel production and the incineration of petroleum products. The most significant figures worldwide are to be found in coal combustion and the informal gold mining in small-scale mines where gold is extracted with mercury from the ore using very basic tools.

The comprehensive report on the measurements and risk assessments can be downloaded from the SLRS website (www.slrs.ch).

Table 3: Hg emissions of gas-discharge lamps compared with other sources

Type of gas-discharge lamp	Hg load per year	Hg emissions per year	Hg emission per capita and year in CH
Total collected lamps according to statistics	80 – 90 kg/yr	≈ 11 – 13 kg/yr	1.6 mg/yr
– thereof FL tubes – thereof non-tube lamps (energy-saving lamps, high-pressure gas-discharge lamps)	70 – 80 kg/yr ≈ 10 kg/yr	≈ 9 – 10 kg/yr ≈ 1.7 kg/yr	1.3 mg/yr 0.2 mg/yr
Total atmospheric Hg emissions as comparison	**Year**	**Main source**	**per capita and year**
– Switzerland[12]	2011	Steel production, petroleum products	29-53 mg/yr
– Worldwide[13]	2010	Informal gold mines, coal power stations	284 mg/yr

Ueli Kasser

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

Daniel Savi

After graduating in environmental science at ETH Daniel Savi gained his initial professional experience in civilian service for the WWF Zurich. This was followed by a seven-year stint at the SENS Foundation, initially as head of the collection points division and then as head of quality assurance for the SENS label. In his current activity in the office for environmental chemistry he deals with the environmental effects of building materials and ecological issues involving waste recycling.

[11] Hug, G., Renner, N., Survey on mercury concentration levels in processed lamp fractions, SENS & SLRS, Zurich 2010, www.eRecycling.ch

[12] Consumption and residue mercury in Switzerland with scenarios for future regulation. Draft dated 5 November 2012. Swiss Federal Environmental Agency (BAFU)

[13] UNEP, Global Mercury Assessment 2013, Sources, Emissions, Releases and Environmental Transport. UNEP Chemicals Branch, Geneva, Switzerland, 2013

[14] See footnote 11

Photovoltaics setting a trend – recycling solar cells

The solar sector is booming – at least that is the perception presented to us by the media. The demand for alternative power generation is huge and continues to grow. It is being pushed not least by falling module prices, attractive cost-covering fee subsidies (abbreviated in German as KEV) and the trend of having your own photovoltaics system on the roof. In Switzerland, KEV is the state programme for promoting renewable energies. Among other things, it remunerates power generated by photovoltaics and returned to the grid at a preferential price. However, the KEV prices are not specified by the government, but rather are adjusted in line with the falling acquisition and installation costs, and therefore in line with market conditions.

The situation is a different one for the manufacturers in the sector: due to the government subsidy programmes in Europe, demand for photovoltaics has increased hugely, prompting the industry to greatly expand its production capacity. The recession and decline in subsidy programmes have created a drop in demand. However, the industry had already increased its capacities. The resulting excess supply has produced overfilled warehouses and price cuts. Uncertainty and hesitant government policies (for example by restricting the KEV) have created a cautious approach in the industry. The industry is under immense pressure.

How will the market react to demanufacturing?

The first photovoltaic systems are now about 15 years old and are slowly reaching the end of their useful life. These systems will therefore soon need to be taken back and disposed of. The quantity of photovoltaic modules currently being recycled is quite low, and the photovoltaic recycling sector is still in its infancy. What is the current status of the technology and research?

Overview of photovoltaic technologies

The following explanations merely provide a rough overview of the rapidly changing world of photovoltaic module types. In general, today's photovoltaic modules can be divided into two broad categories: silicon-based and non-silicon-based. The non-silicon-based modules are known in the market as thin-film modules such as those used in watches. Their advantage is the favourable and energy-efficient manufacture. However, efficiency levels are not high. In the case of silicon-based modules, a distinction is made between polycrystalline and monocrystalline modules, which in terms of use, however, are only marginally different. They have the advantage of being highly efficient. On the other hand, they are expensive and energy-intensive to manufacture. There are many other module technologies that are not listed here because they still have a very low market share.

Research on recycling

For current energy generation, silicon-based photovoltaic modules are predominantly used because their efficiency levels are considerably higher than those of thin-film modules. However, manufacturing pure silicon, which in turn is required to manufacture silicon-based photovoltaic modules, is extremely expensive. For this reason a non-destructive method of recycling individual photovoltaic modules would be of considerable interest. Such a procedure is described as "high-quality recycling".

In high-quality recycling, the aim is to process the module so it can be reused as a new module – it is restored to its raw condition. In pilot systems the recovery quota is amazingly high. However, this involves manual processes and small quantities. Many companies that dealt with on high-quality recycling have already discontinued their business activities. None of them went beyond the status of pilot operations. Only very few companies remain active in the market. Most of these companies process waste modules from production because at present far too few end-of-life modules are handed in for recycling. However, in terms of the technical processes, a leader has yet to emerge.

By contrast, flat glass recycling is low value recycling. It crushes all photovoltaic modules using the conventional method to create the smallest possible fractions so that the raw materials are easier to recover. However, this method only enables the economic recovery of a very small number of raw materials. This downcycling prevents most of the materials being returned to the value-added chain.

Precondition for successful recycling

For recycling to be a viable undertaking, the quantity of returned modules must increase. Only then can the small quantities of valuable metals be recovered at reasonable cost. According to the first, rough estimate, such a quantity will only become a feasible dimension in Switzerland in about 20 to 30 years' time (in Europe in about 10 to 20 years' time). That is why all the companies involved with recycling technologies on a global scale only recycle small quantities and therefore use manual processes. In addition, the increase in the efficiency of the photovoltaic modules and the saving in raw materials during the manufacture of modules are inversely proportional to the recycling potential: The less material used in the manufacture of the modules, the greater the quantity of end-of-life modules required to make the cost of separating the materials worthwhile. This situation presents a challenge at present.

What is specified by law?

Switzerland and the EU are adopting similar policies in terms of legal requirements on the treatment of photovoltaic waste. Until now disposal of PV waste has not been subject to regulation. However, since the quantity of waste is set to increase sharply in the near future, regulation is now considered necessary. The EU has taken a first step with the incorporation of photovoltaic modules in the electronic waste directive (Waste Electrical and Electronic Equipment, WEEE). Switzerland likewise intends to regulate this through the revised Regulation on the Return, Take Back and Disposal of Electrical and Electronic Equipment (VREG). However, high-quality recycling is not specified in either of the two directives, and downcycling is not prevented by law. Therefore, the WEEE Directive merely specifies that materials are to be recycled according to best practice or in line with the latest technological developments. However, both directives do agree on one aspect: materials must be collected separately.

Recycling solar cells – what next?

Photovoltaic systems are being installed in increasing numbers. This means that at some stage the recycling of solar cells will become both a necessity and economically attractive. However, several steps need to be taken to bring about such a situation. The SENS Foundation is already actively addressing this topic, and has established contact with well-known representatives from the sector. The SENS Foundation will therefore be shaping the future and exerting a positive influence on the recycling of materials.

Roman Eppenberger

Roman Eppenburger completed his studies at ETH Zurich, graduating as an electrical engineer. In tandem with his professional activities, he completed the post-graduate course Executive MBA at Fachhochschule Ostschweiz. He gained his first industrial experience as an engineer and project manager in the field of medical and pharmaceutical robotics. As a project manager, he moved to the Contactless Division of the company LEGIC (KABA), where he was responsible for the worldwide purchasing of semiconductor products. From 2012 Roman Eppenberger has been a member of the management board of the SENS Foundation, and is the Head of the Operations Division. In this position he co-ordinates the Technical Commission of SWICO/SENS in conjunction with Heinz Böni.

CAR ELECTRONICS – SWICO

Car electronics disposal

The modern passenger car is a prime example of the advance of new technology in our everyday activities. Increased demands regarding communication, security as well as energy supply mean that electronics are being applied to ever more functions in our cars. Accordingly, the number of electronic or electronically-controlled components in vehicles is also increasing. For 2010 it is estimated that electronics accounted for approx. 30 % of the entire material value of a vehicle. The fact that this is rarely taken into consideration in the processing of scrap vehicles is hard to believe.

The recovery of rare metals[15] from electronic applications is a logistical and technological challenge due in particular to the significantly lower concentration levels compared to the traditional industrial metals such as steel or aluminium. Knowledge of concentration levels and how rare metals are distributed among the corresponding components, and in a passenger vehicle overall, are basic prerequisites for recovering rare metals from car electronics. One of the few major surveys to address rare metals in car electrics and electronics was carried out as part of the EU co-financed SEES project (2006).[16] However, comprehensive and more in-depth knowledge about which concentration levels of rare metals are contained in scrap vehicles is largely lacking to date.

To intensify efforts geared towards the recovery of rare metals from car electronics, the Swiss Federal Office for the Environment (FOEN) has launched the "Recycling Potential of Rare Metals in Car Electronics" project (Diagram 1). The motivation driving this project is based on evaluating the economic and ecological viability of recovering rare metals from car electronics in Switzerland.

A number of relevant organisations are involved in this project including: FOEN, the Office of Waste, Water, Energy and Air (WWEA), the Association of Official Car Collection Points/Holders in Switzerland and the Principality of Liechtenstein VASSO), the Foundation Auto Recycling Switzerland (SARS), Automobil- und Motoren AG (AMAG), the Association of Swiss Car Importers (auto-schweiz), Sustainable Engineering Network Switzerland (SEN) and the Swiss Federal Laboratories for Materials Science and Technology Empa. Now that the planned dismantling and shredding trials have been conducted, Module 3 of the project, "Evaluation and discussion of results", is currently under way.

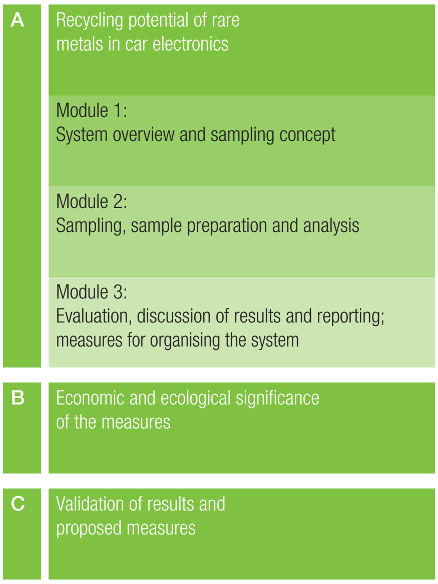


Diagram 1: Components of the "Recycling potential of rare metals in car electronics" project

15 Metals are deemed "rare" if they occur in the earth's crust in average concentration levels of less than 0.001% by weight.

16 Sustainable Electrical & Electronic System for the Automotive Sector; see also: http://www.sees-project.net/

17 From 2005 to 2009 the number of shredded vehicles according to SARS (2011) dropped continuously from approx. 130,000 to 60,000 (see also Diagram 4), and in 2010 increased again to 80,000 vehicles. The number of shredded vehicles is conditional on the respective market situation (general economic situation, metal prices and export restrictions etc).

Swiss car market

Diagram 2 summarises the quantity flows in the Swiss car market for 2010. In that year 4.1 million passenger cars were registered, and almost 300,000 new vehicles were sold. In the same year, the Swiss customs administration registered 90,000 vehicles as exported, while almost 80,000 vehicles were shredded in Swiss shredder plants[17]. On average, vehicle registration documents are cancelled 15 years after vehicles are initially registered. Upon delivery to a shredder plant, a drained vehicle weighs 850 kilogram on average.

Diagram 2: System overview passenger cars, Switzerland 2010. (WIP = Waste Incineration Plant)

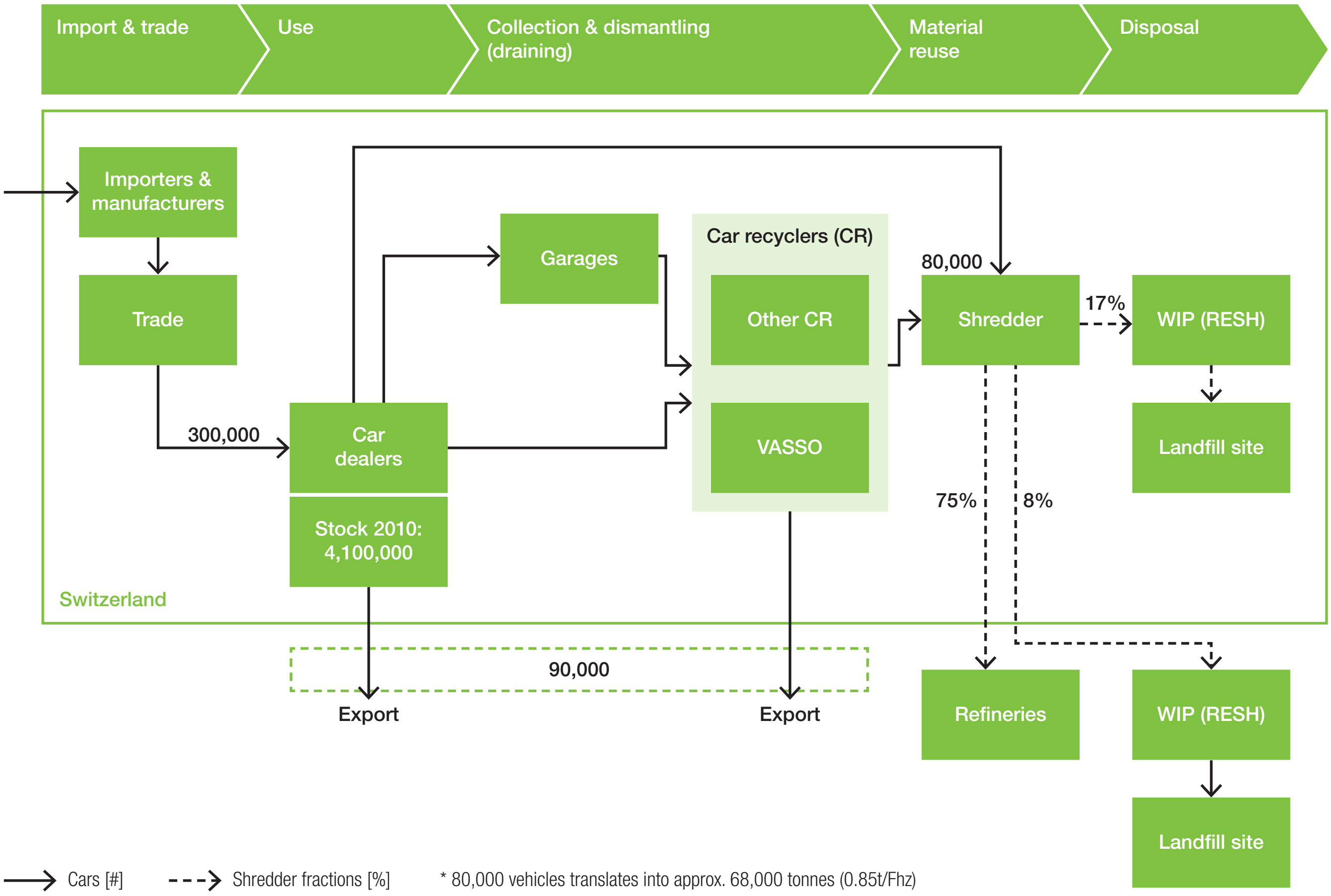
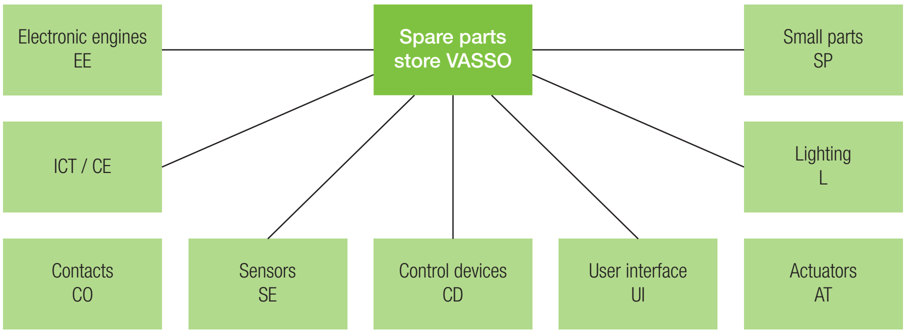


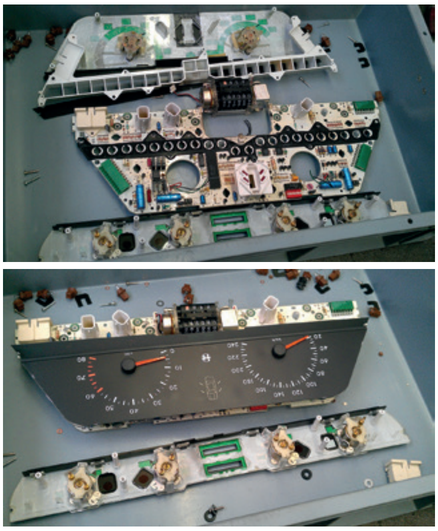
Diagram 3: Categories of electronic components (ICT/CE = information and communications technology & consumer electronics).



Dismantling trials

About 100 kg electronic and electrical car components from the six groups EE, ICT/CE, CO, SE, CD and UI (Diagram 3) were dismantled at Dock St. Gallen (Swico/SENS dismantling facility) and at Empa (Diagram 4). The dismantling trial is aimed at assessing the distribution of rare metals in the input materials of mechanical processing.

Diagram 4: Dismantled components and prepared samples from car electronic equipment



Dashboard instrumentation dismantled

Centre consoles (climate control/entertainment), before and after dismantling

Shredding trial

A shredding trial was undertaken at the plant operated by Thommen AG, Kaiseraugst (SENS recycling company) with a total of 100 vehicles weighing approximately 95 tonnes (Diagram 5). The shredding trial was aimed at assessing the loads of rare metals, and how they are distributed among the output fractions.

Analysis results

Existing methods needed to be tested and adjusted to determine the concentration levels of rare metals in the various fractions. An initial, preliminary evaluation of the analysis results for the output fractions shows that the rare metals are to be found, above all, in the aluminium and iron fractions.

Diagram 5: Shredder input and samples from the output fractions

SLF: *shredder light fraction*
Fe clean: *iron fraction*
al rough: *aluminium after eddy current separator 1*
al fine: *aluminium after eddy current separator 2*
Sieve: *sieve drum fraction*
Rust-free rubber: *CrNi, rubber, wood, ...*
Returns: *various fractions to be returned to the shredder*

Rolf Widmer

Rolf Widmer graduated as an electrical engineer at ETH and then completed a multidisciplinary masters course (MAS) in development and cooperation (NADEL) at ETH, Zurich. For several years he conducted research at the Institute for Quantum Electronics at ETH, and today works at the Technology & Society Lab of Empa, the materials research institute of the ETH domain. Rolf Widmer is currently managing several projects involving electronic waste management and specifically, closed electromobility material cycles. He is particularly interested in recovering rare metals that can be found in increasing quantities in "urban mines".

Patrick Wäger

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

International links

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

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

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

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

National inks

www.eRecycling.ch

www.swicorecycling.ch

www.slrs.ch

www.e-waste.ch
An overview of the Swiss operators involved in recycling electrical and electronic equipment.

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

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

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

Cantons with devolved powers

www.awel.zh.ch
On the website of the Office of Waste, Water, Energy and Air (WWEA), the section "Waste, Raw Materials and Contaminated Areas" provides a raft of information of direct relevance to the recycling of electrical and electronic equipment.

www.ag.ch/bvu
On the website of the Department for Construction, Traffic and the Environment of the canton of Aargau, the section «Environment, Nature & Agriculture» provides further information on the topics recycling and re-using raw materials.

www.umwelt.tg.ch
On the website of the Agency for the Environment of the canton of Thurgau, the section "Waste" provides relevant regional information about the recycling of electrical and electronic equipment.

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