Batch tests: Is a performance comparison possible?

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With the objective of evaluating compliance with the recycling and recovery quotas specified in the Swico and SENS eRecycling technical regulations, regular batch experiments are conducted at the processing partners of Swico and SENS. To achieve better comparison, batch testing was carried out at Swico with a predetermined input amount in 2015. The aim is to find out how the quotas achieved by the various companies during recycling differ and to clarify whether a performance comparison is possible.

The demand on the input material of a batch test (test batch processing according to CENELEC 50625-1) is to process a representative amount of devices at goods-in. Due to the different compositions of the input at the various recycling companies, the results of these tests, however, are not fully comparable. Repeatedly, the poor quality of the material batch was given as a reason by the recycling partners for only just achieving the quota.

Since the introduction of the market basket analysis 2.0 (see Technical Report 2015), Swico has now been able to determine the composition of the market basket in detail. Thus groups, devices, components and even the condition of the devices (e.g. with/without the cable or battery) can now be recorded. The flow of goods can be directly assessed either at the collection point, at the recycling company or even customised (e.g. by manufacturer, product type, age, etc.). These analytical options permit tailoring the input of a batch test close to reality and thus carrying out closely equivalent batch test at the various processing partners (cf. "test batch processing" according to CENELEC 50625-1).

Input composition and processed quantities

In 2015, Swico, together with Empa, launched a pioneering project in Europe: the implementation of a batch test with customised input quantities. The mixture of different information and communication technology device types (Category 3 according to the WEEE Directive) as well as consumer electronics (Category 4, without photovoltaics) was defined so as to correspond roughly to the average composition of the material flow in the Swico system, whereby monitors are not included, since these are processed in a separate recycling channel. The resulting composition is shown in Table 1.

Recycling and recovery rates

In Switzerland, the existing legal requirements of the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE) of 14 January 1998 do not require minimum recycling and recovery rates. In the discussion paper for the revised ORDEE, no minimum quotas are given either. This is in contrast to its counterpart at European level, the WEEE Directive[1], which already provided such minimum quotas in its initial version of 2003.

The processing requirements of Swico and SENS have called for minimum recycling and recovery quotas since 2008. The recycling quota specifies the proportion of the material – relative to the total amount of devices processed – which is re-utilised (recycling), while, in addition, the recovery quota takes into account the portion which is thermally processed. According to the current version of the Swico and SENS Technical Regulations, a recycling quota (RQ) of 65 per cent and a recovery quota (VQ) of 75 per cent for Category 3 (IT and telecommunications equipment) and Category 4 (consumer electronics) must be achieved. These minimum quotas apply even if no monitors are currently included among the devices.

Since 15 August 2015, in accordance with the European WEEE Directive, stricter requirements apply. The minimum quotas were increased by 5 per cent so that the minimum quotas for Categories 3 and 4 now are 70 per cent for recycling and 80 per cent for recovery, respectively. Swico and SENS have not yet introduced the tougher quotas, so the previously existing minimum quotas still apply.

Table 1: Conditioning of the batch

Device types	Specification in t and %		Max. deviation *
PCs/servers	2,850	23.9 %	2.9 %
Printers	2,570	21.6 %	2.5 %
Radios	2,000	16.8 %	0.5 %
Boxes/loudspeakers	1,470	12.3 %	0.5 %
Landline telephones	750	6.3 %	5.3 %
Keyboards	630	5.3 %	0.7 %
Notebooks, laptops, PowerBooks	600	5.0 %	1.6 %
Switches	450	3.8 %	0.1 %
Routers/modems	300	2.5 %	0.1 %
Amplifiers	300	2.5 %	0.1 %
Total	**11,920**	**100%**	

* Maximum deviation from the specification for the respective device types (only five of six companies taken into account).

Implementation

For the assessment of the roughly 12 tonnes of input material, the material was composed over a period of about three weeks together with two employees from the appropriate disposal area of the recycling company. Subsequently, the waste electronic equipment was handed over to the respective recycling company. The recycling companies first had to dismantle the devices as in normal operation and then process a part of them mechanically. Empa was present for some of the initial dismantling and for the whole of the mechanical process. In each case, the entire processing procedure was mapped in a detailed process flow chart according to CENELEC 50625-1, Annex C. All internal and external material flows were recorded; at some recycling companies up to 50 fractions were identified. Of the total input amount, up to approximately 40 per cent was manually dismantled and did not undergo mechanical processing.

The experimental data was transferred to the RepTool[2] reporting tool developed by the European WEEE Forum for the evaluation of the RQs and VQs. With this tool, each fraction is assigned a processing procedure, which creates new fractions, which in turn are processed in other procedures. This process chain continues until all fractions have been recycled or disposed of. This also applies to the further processing by secondary purchasers, in particular to the treatment of mixed fractions for recovery of metals and plastics. Thus, it is vital to know how the external processes run and what quotas are achieved there. This information comes either from recycling investigations at the recycling company or the secondary purchaser, from material flow evidence, in which the purchaser declares the process and fractions, or, for known processes, from literature.

Batteries and capacitors

In addition to capturing the individual material flows, all batteries and capacitors removed were collected. For the battery mixture, the aim is to determine the mass fraction of the lithium batteries and their energy content and condition. For the capacitor mixture, analyses of the ingredients need to be carried out if required, in particular of the electrolytes. Furthermore, samples of the fine fraction (dust and ASR) were taken at the recycling companies. These were examined for PCB, copper, mercury and cadmium, allowing conclusions to be drawn regarding the removal of hazardous substances.

Results and outlook

The individual results are made accessible in the form of a report to the recycling companies but otherwise remain confidential. The detailed results will enable the recycling company to determine where it still has room for improvement and where it lies in comparison to other recycling companies. For the system operator Swico, it is important to know whether there are big differences between the individual recycling companies and whether the companies can meet the stringent regulations that apply in Europe.

Since not all the tests could be completed in 2015, the full results of the project are not yet available.

The cost of batch tests with conditioned input material are very high. It will thus hardly be possible to carry out annual compulsory tests in this way. However, it may be possible to repeat such tests every three to five years, in order to detect at least some trends in the comparable data.

Figure 1: Selection of fractions from manual pre-sorting.

[1] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE).

[2] www.wf-reptool.org

Refrigerators (reporting period 2015)

Geri Hug & Niklaus Renner

Although no refrigerators are produced in Europe any more whose compressors or insulating foams contain climate-damaging chlorofluorocarbons, a large number of such devices are still sent for dismantling at the end of their service life. In 2015, 360,000 refrigerators or 18,000 tonnes of material were recycled by the four highly specialised Swiss recycling companies, which represents a further increase of four per cent. Around 40 per cent of these appliances are still of the old CFC/HCFC type. However, the proportion of the more environmentally friendly HC devices is steadily increasing.

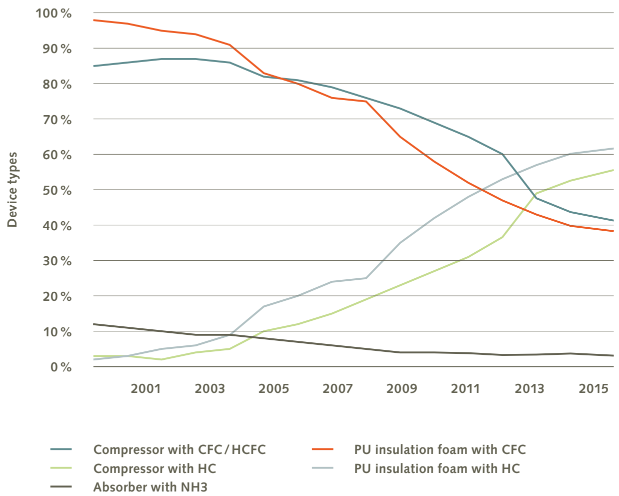

Figure 1: Development of the device types processed at stage 1 (CFC- / HCFC- and HC-containing compressors, ammonia-containing absorption systems) and stage 2 (CFC- and HC-containing PU insulation foam).

HC devices continue to gain ground

In 2015, too, the trend shifted further towards HC-driven compressors: in 2015, already 56 per cent (increase of six per cent compared to last year) of the appliances processed at stage 1 had HC compressors (solid red line in figure 1). Ammonia-containing absorption systems accounted for three per cent of all devices.

For the insulation foams, the survey data shows a similar trend. This became visible here even earlier, because the substitution of R11 by cyclopentane proceeded directly (without the halfway station of partially halogenated CFC as in the case of refrigerants). Currently, the insulation of 62 per cent of the refrigerators entering recycling is made of cyclopentane-foamed polyurethane (PU), so that the increase compared to the previous year too was in the predicted range (increase of two per cent).

As the input, so the output

Despite the continuing high quality of recycling plants, the amounts of recovered refrigerants and propellants is decreasing as more and more HC devices enter the dismantling process. Their compressor-filling quantities or concentration in the PU foam are well below half of that of CFC devices, which is why the absolute recovery quantities (but not the recovery rates) are declining.

Whereas in 2010, 99 grams of refrigerant could be extracted from each compressor at stage 1, last year it was 81 grams, and in the current survey period only 79 grams. Thus, the amount has fallen by 20 per cent since 2010. The amount of oil in 2010 amounted to 217 grams but decreased by 2014 to 186 grams. In 2015, it was 189 grams (–13 per cent compared to 2010). Since a decrease in the compressor oil could also be observed, it seems reasonable to conclude that on the input side, too, lower amounts of oil were used in the more modern appliances.

At stage 2, amounts of around 90 grams per kilogram of PU were still recovered around the turn of the millennium, since when this figure has dropped continuously. In 2014, the amount was 55 grams, while in the current survey year this value had hardly changed at 54 grams (see figure 2). The data is consistent with the moderate decline in the number of CFC housings and the aforementioned decrease in the specific weight of propellant recovered as a mixture of CFC, HCFC and HC.

Recovery of CFC resulted in large CO_2 savings

The ambitious goal defined in the SENS specifications of 90 per cent recovery of refrigerants and propellants is doubly relevant in terms of environmental protection: on the one hand, the CFC contained in compressors and PU insulation foams must be removed from the waste because of their ozone depletion potential (ODP), while on the other hand these substances have a global warming potential (GWP) which exceeds that of CO_2 by one to ten thousand times (see table 1). For this reason, the recovery and subsequent controlled destruction of refrigerants and propellants (and their transformation into carbon dioxide, which is far less damaging to the climate, or dissolving in water as acids or salts) is an important contribution to environmental protection.

Through controlled recovery of the respective substances at stage 1 (refrigerants) and stage 2 (propellants), the quantity of permanent climate-changing gases that the atmosphere was spared amounted to around 390,000 tonnes of CO_2 equivalents in the current survey year. This considerable amount is equivalent to a cube with a side length of approximately 600 metres consisting entirely of CO_2 (see figure 3). The side length of the cube would be over 4.5 times the height of the Zurich Prime Tower.

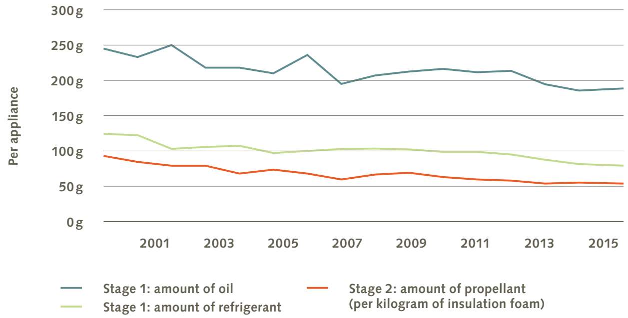

Figure 2: Development of recovery rates at stage 1 (grams of refrigerant, and oil, per appliance) and stage 2 (grams of propellant per kilogram insulation foam).

Substance	Ozone depletion potential (ODP) R11 equivalents	Global warming potential (GWP) with a time frame of 100 years CO_2 equivalents
Refrigerant (stage 1)		
CFC-12 (R12)	1	10,900
CFC-134a (R134a)		1,430
Isobutane (R600a)		3
Propellant (stage 2)		
CFC-11 (R11)	1	4,750
Cyclopentane (CP)		<25

Table 1: Ozone depletion potential (ODP) and global warming potential (GWP) of refrigerants and propellants used in refrigerators. Sources: FOEN (2013), EPA (2016), IPCC (2007).

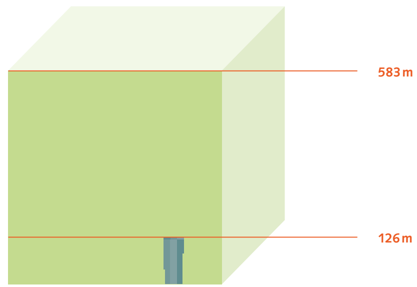

Figure 3: The equivalent amount of CO_2 saved through the controlled dismantling of refrigerators in 2015, represented as a cube of CO_2 (under normal conditions) – compared to the Zurich Prime Tower.