A circular economy for WEEE recycling: Are we heading in the right direction?

Heinz Böni and Rolf Widmer

Waste electrical and electronic equipment (WEEE) contains a range of materials with different properties. Mobile phones, for example, need to contain around 40 different metals in order to function. The presence of economically valuable materials, rare materials that may not be economically valuable, and materials with toxic or hazardous properties in the same device or appliance makes recycling a highly complex process.

WEEE recycling currently has two main goals: (1) the recovery of recyclable material and (2) the removal and environmentally friendly recycling or disposal of hazardous substances.

In Switzerland, the WEEE goes through an initial manual sorting process following collection. This involves removing parts and components that contain particularly dangerous hazardous substances and high proportions of recyclable materials. The waste from this process is then mechanically processed at facilities in Switzerland, with the fractions being either recycled or thermally processed, or taken to specialised final processing facilities abroad, where metal, individual plastic polymers in particular can be recovered directly or by means of a chain of processes. The percentage of raw materials that can be recovered during the final treatment process is massively affected by the type and quality of the method used for pre-processing work and its effectiveness. In other words, the first step of the process is the decisive factor for ensuring the materials end up in the right place and can be recycled rather than being lost and disposed of as waste.

The SN EN 50625 series of standards defines the administrative, organisational and technical requirements that apply to the entire WEEE treatment chain, from collection to recycling or disposal. Specifically, they contain quantitative indicators for evaluating and monitoring the performance of WEEE treatment processes. There are target values for the removal of components containing hazardous substances such as capacitors or batteries, limit values for hazardous substances such as polychlorinated biphenyls (PCBs) or cadmium (Cd) in the mechanical processing residues in the finest non-metallic fraction, and there are performance requirements for recovery based on target values for recycling and recovery quotas and yields for copper (Cu), gold (Au), silver (Ag) and palladium (Pd) in specialised copper smelters.

In order to determine the recovery rate of material from electronic waste that is recyclable or can be recovered in the form of energy, the recycling and recovery quotas are determined based on standardised tests. The recycling quota (RcQ) puts the total mass of base metals and plastics recovered and reusable in relation to the total mass of appliances processed. In addition to the RcQ, the recovery quota (RvQ) takes into account the mass of thermally recoverable materials, i.e. those materials that cannot be recycled, but which have a usable energy content that can replace other energy sources. For WEEE, this mainly applies to plastics whose content of hazardous substances is above the legal limit and that therefore have to be thermally processed.

Both quotas are proportions of the total mass, which does not take into account the main quality concerns for the treatment of WEEE:

- In the case of RcQ, it is mainly high-mass metals such as iron (Fe), copper (Cu) and aluminium (Al) and plastics that determine the quota. This means that substances that are less important in terms of mass, such as gold (Au), palladium (Pd) or silver (Ag), are not included. Accordingly, RcQ does not provide information on the degree of recovery of substances that are less significant in terms of mass.

- The achievable quotas depend on the composition of the input material, which varies in time and space independent of the processing. This means that the RcQ does not provide information on the degree of recovery of a treatment process (ratio between the recovered target substance and its occurrence in the processed WEEE).

- The environmental effects of the recovery of individual materials from WEEE are not recorded despite the fact that the recovery of rare technology metals (RTMs) from WEEE in particular usually has a much smaller environmental impact than producing them from mined materials. This means that the recycling and recovery quotas (RcRvQ) do not provide any information regarding the environmental benefits of treatment.

To determine whether parts and components containing hazardous substances have been removed from the appliances before a mechanical process, certain fractions are analysed to find out how much hazardous substances they still contain, and compared with limit values:

- The comparison of the mass fraction of a target substance in a fraction to its limit value is independent of this fraction mass. This is suitable for a single measurement, but unsuitable for maintaining an overview. This is because the important information about how the total mass of the hazardous substance is distributed among all fractions is lost, especially for those where the hazardous substance can no longer be separated. For example, at first glance, a dust fraction with a PCB content of 60 ppm is more problematic than a shredder light fraction (SLF) with a PCB content of 10 ppm. However, if the fraction masses are taken into account (for example 20 kilograms of dust and 2,000 kilograms of RESH), it becomes clear that the dust fraction contains "only" 1.2 grams of PCBs, while the SLF fraction contains 10 grams of PCBs. Both fractions are currently incinerated, which eliminates all PCBs. However, the fact that at a limit value of 50 ppm the monitoring is blind with regard to the larger load of PCBs is problematic. This becomes a matter of concern when significant amounts of PCBs below the limit are recycled via plastic fractions. There is thus a risk that hazardous substances are not detected or are knowingly recycled together with the polymers and thus kept in the cycle.

- The assessment is based on a small number of hazardous substances. Hazardous substances that are not monitored include asbestos, other substances of concern in capacitors, chlorinated paraffins, phthalates, antimony (Sb) and chrome (Cr).

The weaknesses of the current indicators described above suggest that they give an incomplete, distorted or even wrong picture of the quality of recovery of recyclable materials and of the removal of hazardous substances from WEEE and thus do not meet the requirements of a recyclable waste management system. A successful circular economy must be able to ensure that the end products of the recycling process are of the same quality, or that they are separated and disposed of in an environmentally friendly manner. To achieve this goal, indicators are needed to assess both the circularity of the target substances and their environmental impact. This means that the recovery of the highest amount of recyclable materials is not by default the best result for the environment. Indicators that meet the aforementioned requirements have a positive steering effect towards a sustainable circular economy. The objective of the further development of the indicators is to improve the WEEE treatment with regard to the recovery of recyclable material and the removal of hazardous substances, taking into account the environmental impact, by means of an appropriate methodology and appropriate indicators.