polinares
EU Policy on Natural Resources

POLINARES is a project designed to help identify the main global challenges relating to competition for access to resources, and to propose new approaches to collaborative solutions

POLINARES working paper n. 20
March 2012

The contribution of recycling to the supply of metals and minerals

By Luis A. Tercero Espinoza

EUROPEAN COMMISSION
European Research Area
SEVENTH FRAMEWORK PROGRAMME
Funded under Socio-economic Sciences & Humanities

The project is funded under Socio-economic Sciences & Humanities grant agreement no. 224516 and is led by the Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP) at the University of Dundee and includes the following partners: University of Dundee, Clingendael International Energy Programme, Bundesanstalt fur Geowissenschaften und Rohstoffe, Centre National de la Recherche Scientifique, ENERDATA, Raw Materials Group, University of Westminster, Fondazione Eni Enrico Mattei, Gulf Research Centre Foundation, The Hague Centre for Strategic Studies, Fraunhofer Institute for Systems and Innovation Research, Osrodek Studiow Wschodnich.

8 The contribution of recycling to the supply of metals and minerals

Luis A. Tercero Espinoza

Metals and minerals are generally not destroyed with use but can be recovered and recycled. Recycling is often an effective way to reduce pollution and save energy, as well as to supplement the supply of primary raw materials, thus contributing to the preservation of natural resources and providing a source of raw materials that is independent of local geology. This chapter outlines the distinction between recycling of pre- and post-consumer scrap by defining two cycles of metals/minerals use: that of transformation of raw materials into useful products and the cycle of using metals and minerals in society. Furthermore, the question is approached as to whether, in principle, our demand for raw materials may be met by recycling. Finally, drivers and hindering factors for increased recycling are explored and an overview of current recycling rates is given.

8.1 Introduction

Unlike energy raw materials which are consumed irreversibly through their use (demand = use = consumption), non-energy raw materials offer, in principle, the possibility of re-use in different forms (demand = use ≠ consumption). The most versatile form of using materials again is recycling because recycled material can potentially be used in all demand sectors as opposed to e. g. re-using old parts for which applications are intrinsically limited.[1] In practice, however, not all discarded material is recyclable due to economic and technological constraints and the steadily increasing demand prohibits the complete satisfaction of demand from secondary sources. Thus, the total supply of a non-energy metal may be visualized as depicted in Figure 1, namely, as the sum of raw material from primary and secondary sources. Secondary sources may in turn be split into recycling from post-consumer products (old scrap) and recycling of production waste (new scrap).

[1] These are two of the "three Rs" in solid waste management: reduce, reuse and recycle.

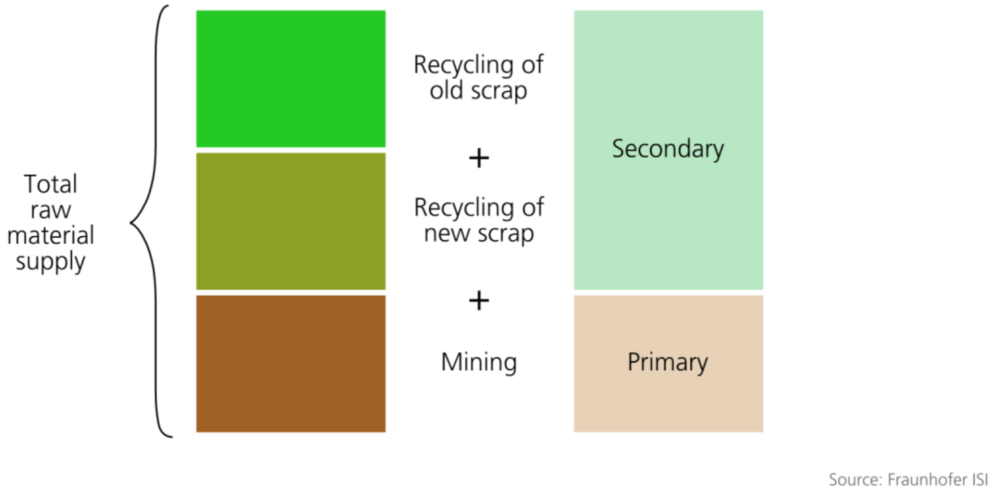


Figure 1: Conceptual break-up of total supply of a non-energy raw material. Note that the size of the boxes does not correspond to the actual contribution to total supply.

Unlike for metals, the recycling of minerals is not widely practical. However, the demand for virgin minerals can be reduced by recycling the corresponding useful materials. This material may be a metal as is the case for bauxite/aluminum: it is not practical to "recycle" bauxite but by recycling aluminum the need for virgin bauxite to produce aluminum is reduced. The same applies to recycling of sand/glass: the need for fresh silica sand is reduced to the extent that glass is recycled.

8.2 Distinguishing between recycling of pre- and post-consumer scrap

The distinction between recycling from old (post-consumer) scrap and new (pre-consumer) scrap is an important one: although the term recycling is used in both cases, the cycles they refer to are different in terms of time and complexity. The recycling of new scrap occurs within the process of transforming metals into useful products, as illustrated in Figure 2. Thus, new scrap may in fact be seen as an efficiency measure used during the manufacture of useful products from metal: by bringing together the different stages in the transformation of metals into products into one conceptual box, the recycling loop for new scrap disappears completely within the box.[2].

[2] This is true to a first approximation. In some cases, the metal may not be directly used by the fabricators of semi-finished products and has to go through smelting and refining prior to reuse depending on a number of factors. This is, however, generally a small fraction of the total.

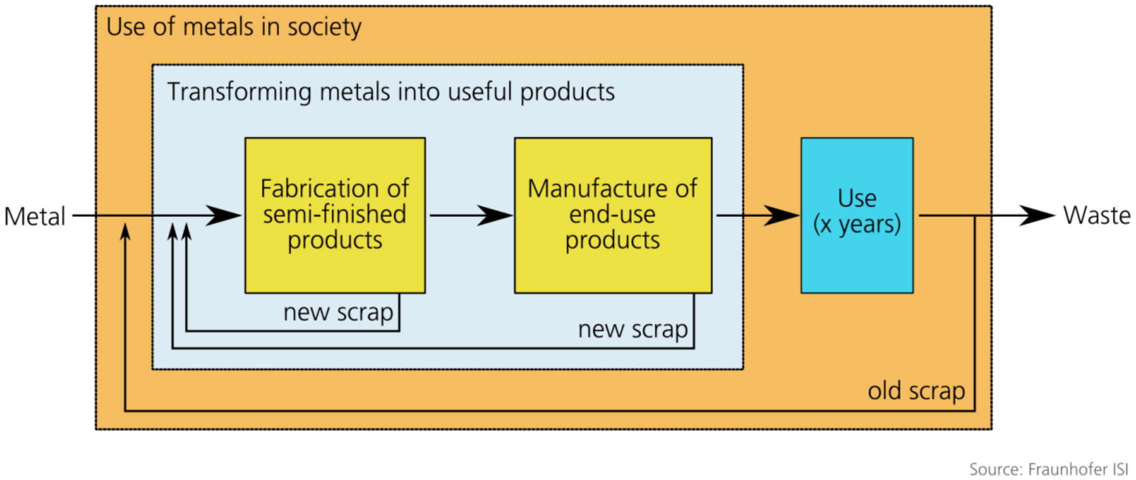


Figure 2: Conceptual scheme of the use of metals in society. The transformation of metals into useful products is generally very fast compared to the useful lifetime of the products. The recycling of new scrap, even if it takes place in different facilities, may be seen as a measure to improve efficiency in the manufacturing process. Notice that this is an approximation because some new scrap cannot be directly used again to produce semi-finished products.

On the other hand, the recycling of material recovered from post-consumer products (old scrap) is part of a larger cycle: that of metals use in society. This cycle includes the production of useful products and their use for a certain period of time (lifetime), as well as material recovery and re-use after the products have been discarded. Thus, the recycling of old scrap is separated from the manufacture of useful products by the useful lifetime of these products, which can range from less than a year (e. g. a beverage can) to several decades (e. g. wiring in a building).

8.3 Can recycling meet our raw material needs?

Because the demand for most metals increases steadily from year to year, even the complete recovery of all metal leaving the use phase (cf. Figure 3) would not lead to a fulfillment of the "new" demand. This point is illustrated in Figure 3. Thus, the relative contribution of recycled material depends on the time lag[3] between primary production and recycling of a given metal because of steadily increasing demand. This time lag is dominated by the use phase in most cases. It is also important to note that material constantly leaves the cycle of metals use in society and metals are in fact irreversibly lost[4] after a number of cycles.

Although it is not possible to prevent metals from irreversibly leaving the cycle of use in society, it is desirable to explore and exploit every reasonable measure to delay their departure.[5]

[3] This is a simplified statement considering the depiction in Figure 42 only. In this graphic, demand is a function of time only and all factors causing the changes in demand (population growth, wealth, technological change, etc.) are masked by this.

[4] This loss is fundamentally different from the consumption of energy raw materials, which are destroyed upon use. The metals themselves are not destroyed; however, their recovery for useful purposes becomes essentially impossible be it for economic, organizational or technological reasons.

[5] It is also possible to delay this by e. g. producing longer lived articles.

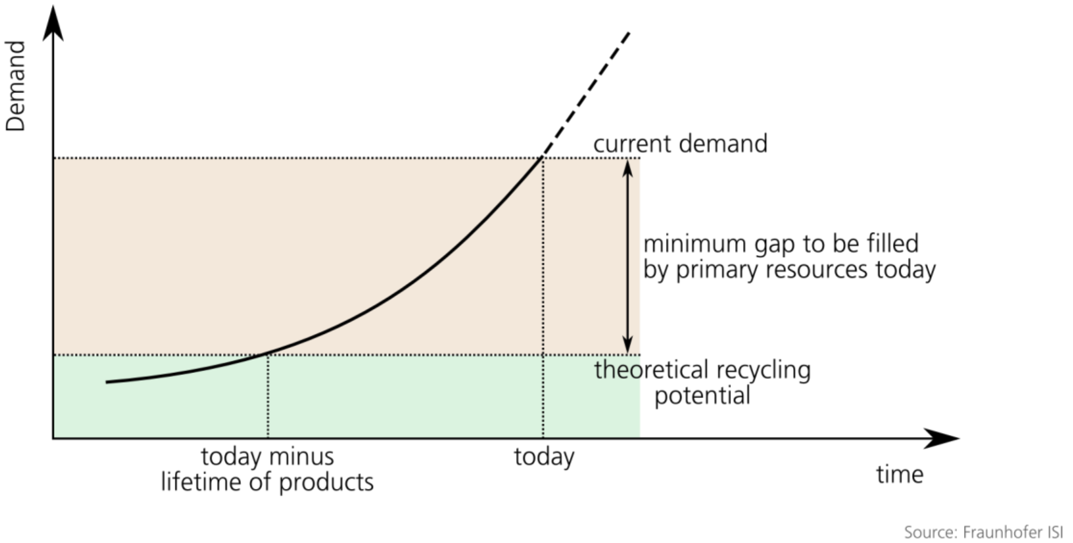


Figure 3: Graphical justification for the need of primary raw materials even in a scenario of 100% recycling of old scrap. Notice that the curve shown represents demand in terms of metal. In practice, this demand is split into different end-use products with different lifetimes, and the demand for metals for specific products may in fact decline or disappear (e. g. through substitution of the metal in the product or of the product itself). Nevertheless, the curve is valid when considering the sum of all products.

8.4 Drivers and hindering factors for recycling

The drivers for recycling include savings in material and energy costs, increasing security of supply, and regulation. Recycling is a cost-reducing measure e. g. when the raw material costs represent an important part of final costs, as is the case for the fabrication of semi-finished products out of copper and aluminum. Because recycling is not always profitable based on material costs alone, regulation plays an important role in promoting recycling measures.

A clear obstacle to recycling, especially of post-consumer products is the complexity of the products themselves. In many cases, considerable effort (e.g. in terms of energy and labor) is required to separate the materials of interest so that they can be recycled. Sometimes an adequate large scale technology is not available (locally or worldwide) to recover the desired materials in a useful quality. This is the case e. g. for phosphors in energy saving lamps, which are to date not recycled on a large scale. In some cases, recycling is possible but too expensive given current technology and prices, forcing downcycling or preventing recycling altogether. An example of downcycling is lithium from discarded lithium ion batteries: it is currently possible but too expensive to produce technical grade lithium carbonate out of recycled lithium (compared to primary production).

Besides technology, however, the success of recycling efforts is tied to the availability of scrap (old and new). In many cases, especially for the so-called “technology metals” which have boomed recently, there is not enough material in circulation or exiting the use phase to justify recycling efforts at a large scale for the purpose of increasing supply security.[6] In case there is enough scrap physically available (i.e. a sufficient quantity of products is reaching the

[6] This may be pursued, however, for other purposes such as environmental protection. It is also important to remember that developing appropriate technologies for large scale recycling is a time consuming process that ideally should be well advanced by the time the scrap becomes available in sufficient quantities.

end of their lifetime), adequate practical availability of this scrap may be thwarted by the absence of a collection system ("organizational" or "logistical" scarcity; for example, the non-collection of small batteries in many parts of the world) or by the unwillingness of owners to part with the discarded products ("wont-give-it-up" scrap scarcity; keeping old mobile phones in a drawer is a typical example of this). Finally, for the purposes of securing supply, the geographically unequal availability of scrap is an issue ("regional" scrap scarcity as a result e. g. of scrap exports). These factors favoring and hindering recycling are summarily shown in Figure 4.

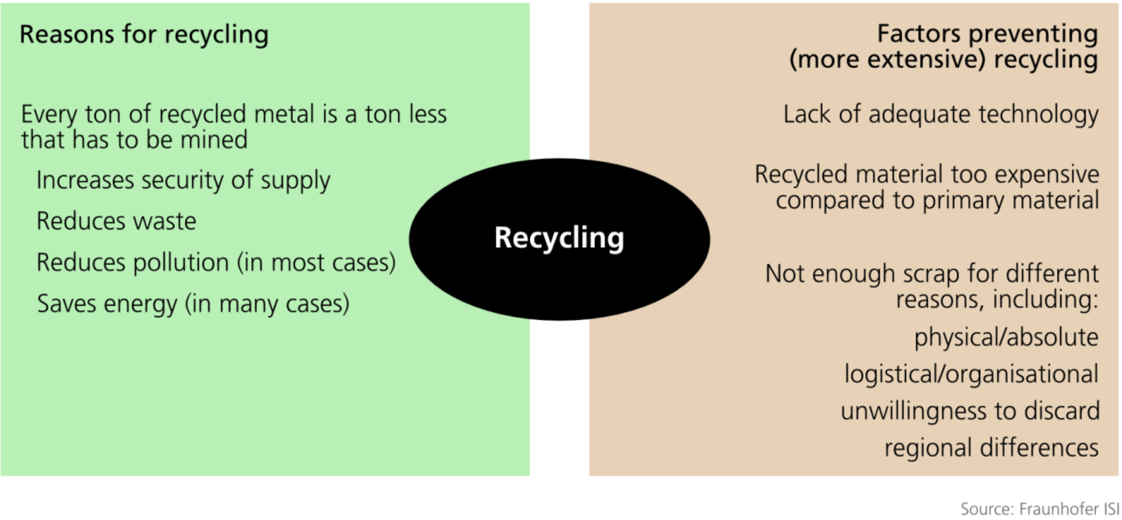


Figure 4: Summary of reasons for recycling and the obstacles found by efforts to establish large scale recycling systems.

8.5 Overview of current recycling rates

Despite recycling being generally recognized as an important part of sustainable resource management, quantitative information available on the success of recycling efforts worldwide is very scarce. Recently, the United Nations Environment Programme (UNEP) released a report on recycling rates of metals prepared by the Working Group on Global Metal Flows of the International Resource Panel.[7] This report brings together published recycling estimates for 60 metals and provides "group consensus" estimates for a small selection of metals. Of the many possible measures for recycling, the UNEP report provides estimates for three:

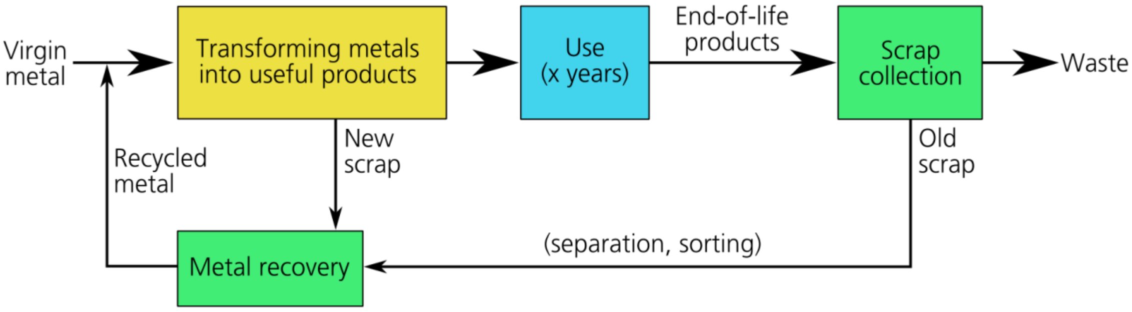
- The recycling input rate: the share of recycled material (from old and new scrap) in current supply;
- The old scrap ratio: the fraction of recycled material that comes from old scrap;
- The end-of-life recycling rate: the percentage of collected post-consumer scrap actually recycled.

The relations given by the recycling indicators are shown graphically in Figure 5, and are a subset of those found in the literature for different purposes. Other possible indicators are the

[7] UNEP (2011) Recycling Rates of Metals – A Status Report, A Report of the Working Group on the Global Metal Flows to the International Resource Panel. Graedel, T.E.; Allwood, J.; Birat, J.-P.; Reck, B.K.; Sibley, S.F.; Sonnemann, G.; Buchert, M.; Hagelüken, C.

collection rate (the efficiency with which metal-containing post-consumer products are actually collected for recycling), the recycling process efficiency rate (the technical efficiency with which collected scrap is transformed to recycled material) and the recycling rate (the efficiency of transforming new and old scrap into recycled metal).[8]

A summary of the recycling estimates given in the UNEP report is shown in Figure 6. It must be kept in mind, however, that although the goal of the report was to collect recycling rates at a global level, this information is often not available. Therefore, the UNEP report relies heavily on information published by the U. S. Geological Survey, which applies only to the USA and is likely higher than the global average. In addition, it is worth noting that the quality of recycling statistics is variable and estimates are often based on assumptions, even for metals used in very large quantities. The recycling input rate should be fairly robust because it can be estimated from data available from producers. All other indicators require more intimate knowledge of the products involved, their individual scrap markets and recycling processes.



$$\text{Recycling input rate} = \frac{\text{Recycled metal}}{\text{Recycled metal} + \text{Virgin metal}}$$

$$\text{Old scrap ratio} = \frac{\text{Old scrap}}{\text{Old scrap} + \text{New scrap}}$$

$$\text{End-of-life recycling rate} = \frac{\text{Recycled metal (from old scrap only)}}{\text{End-of-life products}}$$

Source: Fraunhofer ISI

Figure 5: Simplified depiction of recycling flows and definition of selected recycling indicators. For the sake of simplicity, new scrap is depicted as going directly to metal recovery. This need not be the case; however, pre-treatment of new scrap is often minimal and, in the cases where it is not, new scrap is treated together with old scrap. The effort required to go from collected post-consumer products to metal recovery varies widely depending on the metal and the nature of the product. Recycled metal may not be suitable for all uses (see text).

In addition to the three recycling indicators outlined above, a fourth indicator is included in the plot: the recycling input rate based on old scrap only. This indicator was used in the report

8 See for example EuroMetaux: Recycling rates for metals. Brussels, 2006.

Critical Raw Materials for the EU[9] and quantifies the contribution of recycling of post-consumer products to total supply.

Inspection of Figure 6 reveals that recycling indicators most often range between 0 and 10%, with counts for all recycling indicators generally decreasing as the rate increases with the exception of the old scrap ratio. However, this is only an aggregate view that does not distinguish between different metals. A more differentiated view reveals that there are differences between groups of metals. For example, while ferrous, non-ferrous and precious metals all show moderate to high end-of-life recycling rates, this indicators is almost always very low for specialty metals. The recycling of precious metals from post-consumer scrap is generally higher than for all other groups due to their high value. Notable exceptions to this are mercury (Hg), lead (Pb) and cadmium (Cd) – this is due to human and environmental health and safety concerns rather than to a high value of the metals themselves.

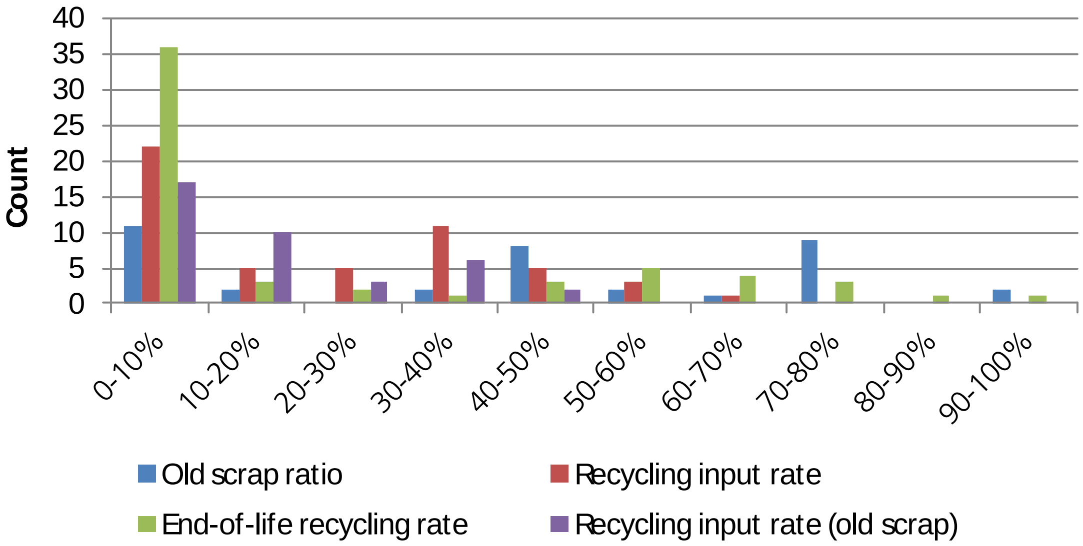


Figure 6: Summary of current recycling rates as compiled by the Working Group on Global Metal Flows of the International Resource Panel. The additional "Recycling input rate (old scrap)" was used by the Ad-hoc Working Group on Defining Critical Raw Materials and is derived from the recycling input rate and the old scrap ratio. Source: Fraunhofer ISI based on UNEP (2011).

Absent from Figure 7 are vanadium (ferrous), osmium (precious), and the specialty metals/metalloids boron, strontium, zirconium, tellurium, barium, selenium, most of the rare earth metals, hafnium, thallium and bismuth. For these metals/metalloids, adequate estimates are missing for one or more of the recycling indicators shown in Figure 7. In most cases, however, estimates of the end-of-life recycling rates are available: for selenium < 5%, for all others < 1%.

Altogether, a picture emerges of more or less mature recycling systems (technology, logistics, and scrap availability) for most ferrous, non-ferrous and precious metals but systems for specialty metals are largely missing.

[9] Critical raw materials for the EU – Report of the Ad-hoc Working Group on defining critical raw materials. Brussels, 2010.

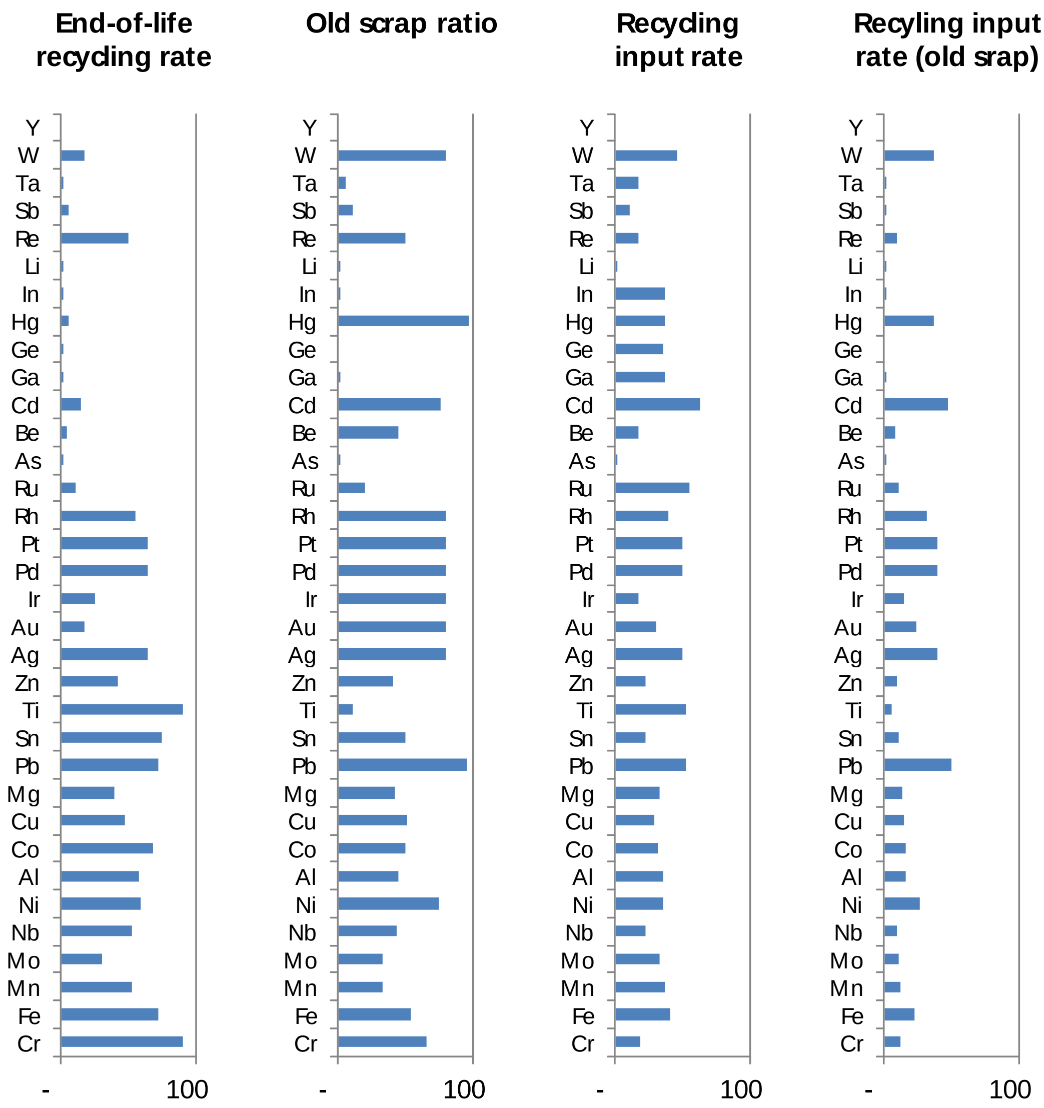


Figure 7: Selected recycling indicators (in %) for 34 metals, starting from the bottom: ferrous (Cr, Fe, Mn, Mo, Nb, Ni), non-ferrous (Al, Co, Cu, Mg, Pb, Sn, Ti, Zn), precious (Ag, Au, Ir, Pd, Pt, Rh, Ru) and specialty metals (As, Be, Cd, Ga, Ge, Hg, In, Li, Re, Sb, Ta, W, Y). This is the subset of the UNEP dataset for which all four recycling rates are given or can be estimated. The average was taken when more than one estimate was available; the "consensus recycling statistic" was taken if provided by the UNEP panel. Source: Fraunhofer ISI based on UNEP (2011).