

Sustainable Recycling of Electronic Scrap

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Gold plays an increasingly important role in industrial applications, particularly in electronics, despite its larger use in jewellery and investment products. As the annual statistics show (Gold Survey 2010, GFMS Ltd, London), some 300t or more of gold are used annually in electronic components such as ICs, contacts and circuitry, the latter notably as gold bonding wire.

Sales growth of electronic devices continues to boom and their in-built features continue to become 'smarter and quicker' each year, which has led to a substantial net increase in gold demand over recent years, even though specific gold content is being driven down due to thrifting and miniaturisation. At the end of their use, electronic and other electrical product scrap offer an important recycling potential for the secondary supply of gold into the market. With gold concentrations reaching 300-350 g/t for mobile phone handsets and 200-250 g/t for computer circuit boards, this scrap is an 'urban mine' that is significantly richer in gold than the sources of the primary ores today. However, as a forthcoming paper points out (C. Hagelüken and C. W. Corti, Gold Bulletin, vol 43 (3,) 2010), the 'mineralogy'

of such scrap products is very different to those of primary ores. Such scrap contains up to 60 different chemical elements that are intimately interlinked in complex assemblies and sub-assemblies. They are usually associated with organic materials that often incorporate halogenated flame retardants. Thus, specialised metallurgical processes with extensive offgas treatments are required to recover the gold and a wide range of other valuable metals in a cost-effective and environmentally sound way. Equally importantly, the collection of such scrap from millions of households and businesses requires organised logistics to collect and bring the scrap to the recovery and refining facilities; this is undoubtedly a bigger challenge than the primary ore supply chain.

Gold's importance to the economics of recovery

Recovery of gold and other valuable metals from such scrap involves a complex metallurgical flowsheet and requires state-of-the-art recovery technologies that are available in large-scale, integrated smelter-refinery operations. At the Umicore plant in Belgium, for example, pure gold and 16 other metals are recovered with high yields.

Perhaps what is not adequately appreciated is that the recovery of gold is important to the economics of recycling electronic scrap. It is the gold that makes the recovery of all the valuable metals economically worthwhile. Thus a 'design for recycling' approach to the use of gold in electronic equipment assumes an importance when material choices are being made by OEMs; simply seeking use of cheaper alternative materials as substitutes for gold can damage the economics of recycling devices at the end of their life. One needs to take the complete life cycle costs into account at the design stage.

This is about sustainability of resources. However, in Europe and elsewhere, there are currently severe deficits in the recycling chain that hinder the achievement of a high overall recovery rate of gold and other metals. This is due in part to substandard processing of scrap in many 'backyard' recycling operations, often through the illegal and dubious export of end-of-life electronics to many developing/transition countries around the world. There is also an environmental impact, as discussed below. We should also note that recycling of WEEE in the EU and elsewhere has become a legal requirement.

The composition of electronic equipment

The materials contained in scrap electronic equipment are large in number and value; some are valuable and some are toxic or hazardous. Typical chemical elements found include:

1. Base and special metals such as iron, copper, aluminium, nickel, zinc, tin, cobalt, indium, gallium and selenium
2. Hazardous metals such as mercury, beryllium, cadmium, arsenic and antimony
3. Halogens – bromine, fluorine and chlorine
4. Other substances such as organics/plastics, glass and ceramics.

If such scrap is landfilled or not treated in an environmentally sound way, then it poses a high risk of environmental damage. The valuable materials that it contains are not recovered and reused, and so this increases the need to mine new metals from primary resources.

Typical compositions of a number of electronic items are shown in the upper part of Table 1. We should note that these figures are indicative; actual content can vary significantly but the magnitude is correct. In terms of weight, plastics and steel tend to dominate, but in terms of value, the lower part of Table 1, gold and the other precious metals dominate. Gold and other precious metals makes up more than 80% of the value in PC boards, cell phones and calculators, and around 50% of the value in TV boards and DVDs. We note copper is next in value terms.

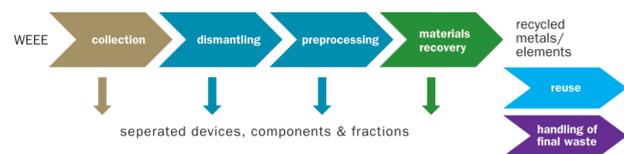


Figure 1: Recycling chain for End-of-Life electronics

The European Directive on Waste Electronic and Electrical Equipment (WEEE) aims to provide a 'closed loop' economy, that is, to foster environmentally sound reuse and recycling, and to preserve natural

Hence, it is very evident that any net decrease in precious metal content substantially reduces the net recoverable value from the electronic scrap and, thus, the motivation to recycle scrap. It is worth noting that the complete recycling chain needs to be remunerated, as Hagelüken and Corti discuss in their paper. The recycling requirements – technical processes and emission controls – depend on the composition of the scrap, and taking the various values between types of scrap into account, means that the mixing of different types of scrap in the collection and pre-processing stages can influence the recycling returns in a negative manner.

Gold: The potential market supply from recycling

The electronic use of gold at around 300tpa amounts to about 12% of the total annual mine production of gold. Its efficient recovery from electronic scrap (WEEE) therefore represents a substantial potential recycling resource. If we take the case of mobile phones, for example, global sales of 1,300 million in 2008 equates to about 31 tonnes of gold, 325t of silver, 12t of palladium and 12,000t of copper. With batteries, an additional 4,600t of cobalt can be added. Taking cumulative sales of mobiles up to 2008, this increases to 170t of gold, 1,800t of silver and 70t of palladium.

If we add the sales of PCs and laptops, these potential supplies of precious metals equate to a significant proportion of total mine production: 4% for gold, 3% for silver, 16% for palladium, 20% for cobalt and <1% for copper. For the broader electronics market, the market supply is more substantial.

The 'green' credentials of recycling WEEE

Being a rich source of gold compared to primary ores, the urban mine of WEEE is economically attractive. If we factor in the high CO₂ impact of primary gold production, the recycling of scrap becomes more attractive from a sustainable standpoint. Recycling has a much lower carbon footprint if state-of-the-art technologies are used. Clearly, WEEE scrap cannot replace all primary gold production; it is complementary in the drive

for a more sustainable use of gold.

The challenges in recycling precious metals from WEEE

There are several stages involved in the recycling of WEEE (see Figure 1), and the overall recovery rate will depend on the efficiency and effectiveness of each stage. The high precious metal yields achieved in the recovery stage, if state-of-the-art technologies are used, are insignificant if only a low proportion of WEE is collected or there is a large loss of gold in the dismantling and pre-processing stages. Today, less than 20% of the gold recycling potential is being realised from European WEEE due to the inefficiencies of the initial stages of the process chain. The collection stage is the weakest part of the chain. There is still a long way to go in Europe, and in many other countries, in organising efficient collection. Governments have a major part to play here and must take this aspect seriously.

The biggest loss factor currently is that much WEEE is exported to countries in Asia and Africa, for example, for treatment or just for discarding. Such scrap is usually treated by low-tech 'backyard' recycling methods that have dramatic environment and health impacts on workers and local communities (see paper by Hagelüken and Corti for further discussion on this aspect). Moreover, treatments are highly inefficient in terms of metals recovery, often focusing on 'cherry-picking' a few valuable metals; even for gold, yields are often lower than 25%.

Concluding remarks

This article has shown that the recycling of gold and other valuable metals from electronic devices at the end of life (WEEE) has a significant potential impact on the sustainable supply of gold and other metals to meet the needs of our modern society. In addition, gold has a vital role to play in the economics of recycling such scrap. Thus, a 'design for recycling' approach is needed in specifying materials used in new equipment manufacture by OEMs, especially gold. Thus, gold is the 'paying metal' that triggers recovery of other scarce precious and special metals that otherwise would not be economic to recover. Such an approach needs to be combined with innovative business models that encourage a more comprehensive collection of consumer goods at their end of life.

There are legal requirements in Europe for a 'closed loop' recycling system under the EU WEEE Directive, but currently this is far from the reality. Too much scrap is exported and poorly recycled, with a consequential damaging impact on environment and local communities. This loophole needs to be closed. Governments and manufacturers of electronic products have a major role to play

here in encouraging efficient collection systems and in enforcing existing legislation. ■

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weight-share	Fe	Al	Cu	plastics	Ag [ppm]	Au [ppm]	Pd [ppm]
monitor-board	30%	15%	10%	25%	280	20	10
PC-board	7%	5%	18%	23%	900	200	80
mobile phone	7%	3%	13%	43%	3000	320	120
portable audio	23%	1%	21%	47%	150	10	4
DVD-player	62%	2%	5%	24%	115	15	4
calculator	4%	5%	3%	61%	260	50	5
value-share	Fe	Al	Cu	sum PM	Ag	Au	Pd
monitor-board	4%	14%	35%	47%	7%	33%	7%
PC-board	0%	1%	13%	86%	5%	69%	12%
mobile phone	0%	0%	6%	93%	11%	71%	11%
portable audio	3%	1%	73%	23%	4%	16%	3%
DVD-player	15%	3%	30%	52%	5%	42%	5%
calculator	1%	4%	10%	85%	6%	76%	3%

Table 1: Value versus weight distribution for typical electronic devices (March 2010 prices)