End of Life of Electronic Communication Devices in the Context of Strategies to Decouple Resources Use from Economic Growth

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Abstract—**Electronic waste (E-Waste), also called Waste Electronic and Electrical Equipment (WEEE), is a topic of high concern due to increasing amounts, possible hazardous effects, but also with view to significant amounts of potentially recoverable materials and especially of elements with limited natural resources such as precious metals. This is particularly the case for electronic communication devices, which represent an essential equipment of our modern professional and private lifestyles, while however being characterized by short lifetimes. WEEE – and again in particular waste electronic communication devices – is a waste stream which is difficult to predict, and recycling is a challenge, but WEEE holds high potential to make significant contributions towards decoupling waste generation and resource consumption from economic growth. Implementation of decoupling approaches in developed and developing countries is significantly different due to unequal levels in availability of data on material streams, state-of-the-art of waste management and recycling, and regulatory frameworks.**

Keywords- electronic communication devices, recycling, waste electrical and electronic equipment (WEEE), precious metals, recovery, decoupling, dematerialization

I. Introduction

Decoupling is an efficient strategy for the conservation of natural resources and a step forward for sustainable development. In traditional economic systems characterized by linear material flows growing economies result in overuse of natural capacities mainly due to increasing consumption of resources, generation of potentially harmful effluents and overuse of final disposal reservoirs. Decoupling strategies comprise all means to break linear dependencies between economic development and requirement of resources/ generation of final waste. Recycling of waste streams and implementation of closed loops (or creation of interlinks between different loops) is one efficient means of decoupling approaches.

This study looks at electronic communication devices with focus on mobile phones and computers. These pieces of equipment are not only a symbol of our modern lifestyle, but at the same time they are both a challenge in environmentally sound waste management and a source for recuperation of precious components.

II. Decoupling

All decoupling strategies aim at fulfillment of scenarios in which consumption of resources and generation of wastes does no longer grow steadily along with the Gross Domestic Product (GDP). Positive implementation will reduce burdens for the environment without reducing chances of economic development. Two main approaches exist [1]:

- Immaterialization
- Dematerialization

Immaterialization includes changes in the perception of values and criteria of well-being/ standard of living (including education, tourism), and as a consequence changes in behavioural patterns (shifts with tendency away from material goods). Immaterialization is the concept which has highest potential to achieve vital progress towards decoupling; however chances for implementation will be very specific for given environments and will depend on factors such as degree of urbanization, structure and functioning of public infrastructures, general lifestyles, economic and political situation. Immaterialization necessitates particularly strong interdisciplinary considerations, and multi-leveled awareness and communication.

Dematerialization covers all means to reduce the quantity of materials required to generate a desired output (including eco-efficient technologies, recycling). Dematerialization has a more distinct technical focus compared to immaterialization; as a consequence methods are better suited to be directly transferred from one country to another one.

Decoupling strategies need to consider and address the actors in all sectors of the economy, from basic production to decision making (see Fig. 1).

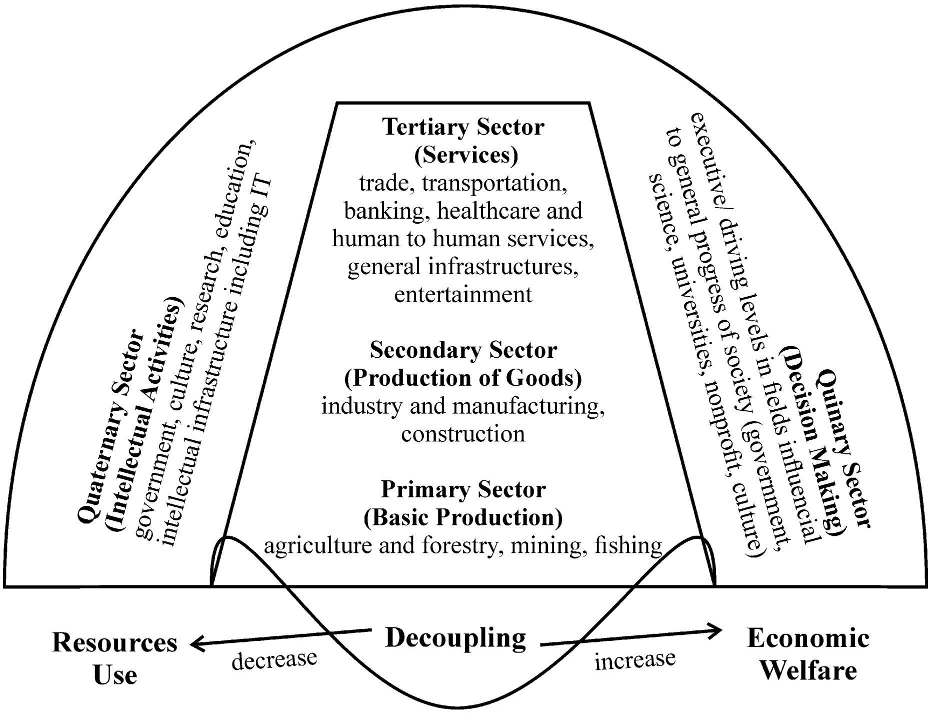

Figure 1. Decoupling as aspired baseline to be implemented in the matrix of the economic sectors

While actual implementation of decoupling strategies in practice – and in particular of dematerialization options – will be highly dependent of adoption in the classical three economic sectors covering mainly production and consumption of goods (the Primary, the Secondary and the Tertiary Sector), the Quaternary and Quinary Sector will be most influential in setting incentives, initiate changes in existing systems, reflect on chances and challenges. They are also most relevant when it comes to immaterialization options – and they are highly dependent on intellectual infrastructure including IT and electronic communication devices.

Quaternary and Quinary Sectors in general gain importance along with economic development of a country and social well-being. The chance of establishing the decoupling attitude and concept not only in existing systems but already in changing environments along their emerging needs and demands is worth to be considered as most promising.

III. WEEE

Waste electrical and electronic equipment (WEEE) is defined as any appliance using an electric power supply that has reached its end-of-life [2]. This includes several types of equipment such as: televisions, refrigerators, freezers, washing machines, cloth dryers, air conditioners, personal computers and monitors.

There is widespread consensus that landfill is not an acceptable management option for end-of-use EEE. Diversion from landfill can be achieved through voluntary or mandatory take back or collection programmes. This typically results in recycling of e-waste with recovery of a limited number of metals [3].

WEEE is one of the fastest growing solid waste streams around the world. Its annual growth rate is 3 to 5%, which is approximately three times faster than other individual waste streams [4] *(citing Schwarzer S, Bono AD, Peduzzi P, Giuliani G, Kluser S (2005) E-waste, the hidden side of IT equipment's manufacturing and use, UNEP Early Warning on Emerging Environmental Threats No. 5, Switzerland, United Nations Environment Program)*. The total amounts are 20 to 50 million Mg of WEEE per year [5] *(also citing abovementioned UNEP report)*.

The European Union designated WEEE a priority stream in the year 1991 and then started elaboration of legislation for a better management of e-waste, but it was only in 2003 that the common Waste Electrical and Electronic Equipment Directive came into legislative effect [6]. The Directive covers ten categories of electric and electronic equipment and defines general requirements concerning mandatory collection and recycling objectives. The actual implementation in individual member states is varying. The states are urged to collect 4 kg WEEE per capita and year.

The European Community expects waste management and recycling to make a significant contribution to recovery of resources. WEEE contains a whole range of metals which are important in industrial production but are not mined in Europe [7]. The amounts of rare metals are relatively high with respect to the worldwide demand [7] – which makes recycling particularly attractive.

Due to technical reasons, WEEE however also contains numerous compounds which are classified as hazardous (e.g. chromate, lead, cadmium, flame retardants) [7]. When looking at the European regulation in more detail, it is evident that initial driving force for e-waste regulations was limitation of hazardous effects associated with this material flow, while focus on recuperation of valuable materials has been placed later in time.

IV. End-of-Life Electronic Communication Devices

Electronic communication devices have become standard of day-to-day life. Rapid changes of technology and necessities arising from rhythms set by production in the industries influence customers' habits and demands. Communication technology is very soon outdated and by creating a constant demand for the newest pieces of equipment the digital economy at the same time generates larger and larger quantities of electronic waste.

Some of the waste is the result of successful criminal offence. Communication and digital equipment with its resources and data have become crucial and therefore susceptible elements of all participation and progress in economic, scientific and cultural life. Very little empirical work exists on the topic, but aside of misconduct on institutional or industrial competitive levels, the concealment and anonymity afforded by electronic communication seems to fit well into patterns to satisfy specific urges of individuals [8]. This might not only result into intrusive activities in order to torment and control a target person, to provoke and subsequently study psychological reactions, but might also include intentional blockage and inactivation of resources and in consequence of activities and initiatives of the target person, and might possibly occur in accelerating intensity in attempts to hide initial and following misconduct.

Computers and mobile phones are not only common in developed countries but are of increasing importance in developing countries as well. In Africa already half of the one billion members of its population have access to a mobile phone and in India every month 15 million mobile phones are added [9]. Today mobile phones have become the most ubiquitous electronic product worldwide [10].

Voluntary take back networks can significantly contribute to tackle the increasing shortage of key metals typically found in mobile phones [10]. Mobile phones are relatively smaller in size compared to other EEE. This has the effect that without further incentives mobile phones will often end as burden for municipal authorities to manage with the regular municipal solid waste stream, even when take back services are available. But their disposal into the domestic waste stream is problematic under the two main aspects of loss of precious materials and of presence of hazardous potential. Implementations of take back services require public support in the growing stages (e.g. in India) [11].

If collected separately, the waste equipment can be processed in order to recuperate significant amounts of valuable resources such as gold. The large variations in composition of devices are a special challenge. Pre-processing influences the recovery of metals such as gold (see e.g. [5]). Pre-processing (carried out manually, mechanically or in combined methods) ensures that materials enter the appropriate recovery way.

Not only the varying composition of devices and the necessity to establish efficient collection infrastructures pose specific challenges, but also the quantities of WEEE. Communication equipment seems to be the dominant WEEE in Africa, poorer regions of Asia and in Latin/South America – but there is need for more accurate and current data [12]. This also needs consideration of future developments in the field in a global perspective.

Aside of entering recycling pathways or in worst case being disposed of in landfills, mobile phones are often reused. According to Geyer & Blass [3] mobile phones are currently one of the few electronic products with an attractive and economically viable reuse market – with the consequence that at present more handsets are reused than recycled (which however includes activities of transboundary transport of equipment).

V. Potential Recovery of Precious Metals from Mobile Phones, PCs and Laptops

Potential recovery of the precious metals Silver (Ag), Gold (Au), Palladium (Pd), Copper (Cu) and Cobalt (Co) was assessed for mobile phones and computers within a study looking at high-grade WEEE [13]. In order to estimate the amounts of precious metals contained in the equipment, the assessment used data published by UMICORE [14]. This section summarizes the findings in order to highlight the possible amounts of potentially recoverable precious metals. The study is based on global sales data for the year 2007, which is taken as static parameter, and for which it is assumed that each sold unit will finally result into a waste unit.

In the year 2007 the global sales of mobile phones was 1,200 million units and the global sales of PCs and Laptops amounted to 255 million units. Assuming an average weight of 125 g for mobile phones and of 2.5 kg for PC/Laptop units, the total amount of mobile phones will be 150,000 Mg/a and of PCs/Laptops 637,500 Mg/a. The potential recovery of the selected five precious metals is shown in Fig. 2 and Fig. 3.

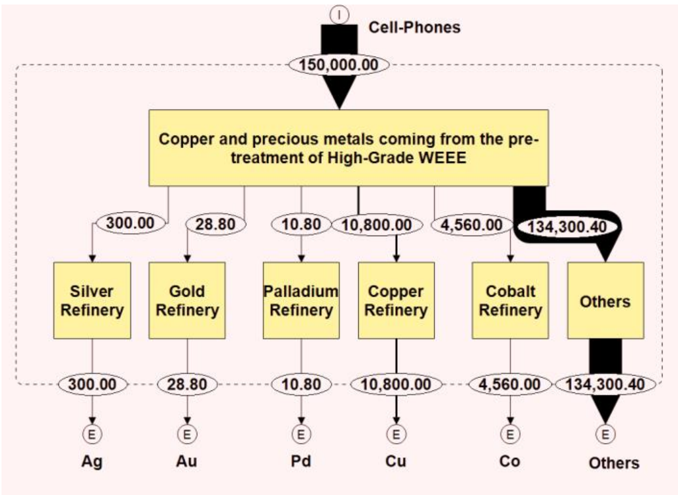

Figure 2. Schematic diagram of global potential recovery of five selected precious metals (Ag, Au, Pd, Cu, Co) from mobile phones (values are reported in Mg/a) [13]

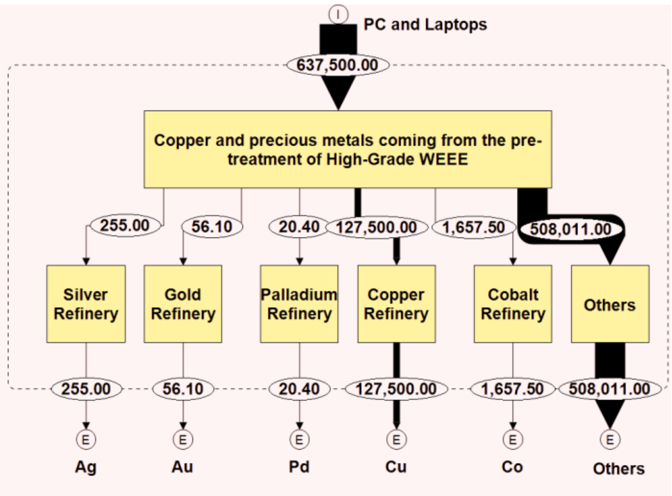

Figure 3. Schematic diagram of global potential recovery of five selected precious metals (Ag, Au, Pd, Cu, Co) from PCs/ Laptops (values are reported in Mg/a) [13]

The potential mass flows of recovery of the five precious metals from mobile phones and PCs/Laptops put in the market in 2007 is summarized in Table 1 and Table 2, along with an estimation of the value of recovery in million $.

TABLE I. AMOUNTS AND VALUE OF POTENTIALLY RECOVERABLE PRECIOUS METALS FROM MOBILE PHONES [13]

Metal	Potential recovery	Price	Value of potential recovery
	Mg/a	*$/kg*	*Million $*
Ag	300	430	129.0
Au	28.8	22,280	641.7
Pd	10.8	11,413	123.3
Cu	10,800	7	75.6
Co	4,560	62	282.7

TABLE II. AMOUNTS AND VALUE OF POTENTIALLY RECOVERABLE PRECIOUS METALS FROM PCS AND LAPTOPS [13]

Metal	Potential recovery	Price	Value of potential recovery
	Mg/a	*$/kg*	*Million $*
Ag	255	430	109.7
Au	56.1	22,280	1,249.9
Pd	20.4	11,413	232.8
Cu	127,500	7	892.5
Co	1,657.5	62	102.8

The study indicates the high economic value of precious metals contained in electronic communication devices. It is worth noting that the amounts contained in mobile phones might be higher for some components (e.g. cobalt) compared to the amounts in PCs/Laptops.

More detailed studies would be essential, also taking into consideration the amounts of electronic equipment as dynamic parameter over time. However the results of the study provide an assessment of the importance of the topic both with view to reduction of use of resources of limited availability and with view to relevance in economic consideration.

VI. APPLICATION INTO PRACTICE

The level of awareness and reaction on the waste generated from electric and electronic equipment differs significantly between developed and developing countries. Evaluation of consumption patterns along with increasing the level of awareness are central questions to have been recognized for example in Jordan [15].

Application of WEEE recycling into practice and therefore steps towards decoupling of waste generation from economic growth in a country such as Jordan would require a series of actions as summarized in the following (also see [13]):

(1) Assessment of the EEE put in the market per year

(2) Estimation of the life time of different categories of EEE

(3) Assessment of the WEEE produced per year

(4) Establishing a national collection system

(5) Estimation of the collection rate of different categories of WEEE

(6) Estimation of the potential recovery of different components from WEEE by applying a decoupling strategy

(7) Establishing recycling and treatment plants for waste separation and recovery

VII. CONCLUSIONS

Decoupling waste generation from economic growth is an essential and efficient strategy for the conservation of natural resources and is a step forward in sustainable development. The most efficient means when aiming towards achieving waste decoupling scenarios is avoidance and minimization of waste. It is then recycling which is preferentially to be implemented, and in particular when looking at components of limited natural resources such as precious metals.

WEEE is one of the fastest growing wastes in Europe and elsewhere. Recycling of e-waste is an efficient tool of dematerialization decoupling which offsets the consumption of natural resources significantly. WEEE in the form of electronic communication devices is not only particularly challenging, but also of special interest with view to recuperation of materials. Lack of data on current and future amounts in different countries and lack of data on composition of devices are particular problems in this field.

Positive decoupling means an optimized resources use along with increasing economic welfare and general social well-being. Progresses towards achieving application of such patterns in practice do not only closely link to sustainable decision making in processes of intellectual and cultural activity with continuous communication, but also to availability and reliability of the necessary infrastructures including in particular IT. Electronic communication devices therefore are not only to be seen as a special challenge in decoupling scenarios when it comes to end-of-life considerations, but at the same time as a most essential prerequisite for positive implementation of decoupling responsibilities in all sustainable development.

Favourable legal frameworks can be among the most influential drivers to complement economic incentives towards implementation of successful decoupling strategies including waste management approaches. While detailed regulations on waste management exist on EU level and in some countries like Germany, the regulatory framework is to be completed in other countries. The fast increase of WEEE and the potential hazardous effects also require an understanding on global level, including transboundary movement of materials. The Basel Convention is the only international agreement about transboundary shipment of e-waste.

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