Decoupling Resources Use from Economic Growth

Chances and Challenges of Recycling Electronic Communication Devices

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Abstract—**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 – represents a waste stream which is difficult to predict, and for which recycling is a challenge. However, WEEE holds high potential to make significant contributions towards decoupling waste generation and resource consumption from economic growth. Decoupling is seen as promising pathway towards increased sustainability along with future economic developments. Implementation of decoupling approaches needs to consider different situations in developed and developing countries, which includes data availability on material streams, state-of-the-art of waste management and recycling, and the individual status of regulatory frameworks.**

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

I. Introduction

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. Such economic growth with depletion of resources along with accumulation of negative environmental effects exerts pressure on sustainability.

Decoupling strategies comprise all means to break the dependencies between economic development and requirement of resources/ generation of final waste. Decoupling therefore is an efficient strategy for the conservation of natural resources and a step forward for sustainable development. 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 waste electronic communication devices with focus on mobile phones and computers, and their possible role in decoupling strategies. 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. The theoretical background and current state of knowledge in the field of decoupling is presented first, and is then followed by a case study on mobile phones and computers.

Main aim of this publication is to provide an insight into current chances and challenges related to recycling of electronic communication equipment in order to facilitate assessment of this product group in scenarios and projects designed and implemented in order to advance on pathways towards decoupling.

II. Decoupling

All decoupling strategies aim at fulfillment of scenarios in which environmental pressure – related to consumption of resources, emissions 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 behavioral 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, design and functioning of public infrastructures, general lifestyles, economic and political situation. Immaterialization necessitates particularly strong interdisciplinary considerations, as well as diversified multi-leveled awareness and communication.

Dematerialization covers all means to reduce the quantity of materials required to generate a desired output. Eco-efficient technologies and recycling are most common elements. Often, this is associated with pollution prevention, efficiency improvement, use of renewable energy and industrial ecology.

These are usually grouped together under the term of Cleaner Production. Dematerialization has a more distinct explicit technical focus compared to immaterialization; as a consequence methods are better suited to be directly transferred from one country to another one.

It is necessary to distinguish between absolute and relative dematerialization. Absolute dematerialization, also referred to as strong dematerialization, occurs when material input to an economy decreases in absolute terms. Relative dematerialization, also regarded as weak dematerialization, refers to a decrease in the intensity of use, requiring the ratio between material input and GDP to fall over time [2].

Decoupling strategies can refer to a global perspective, to national economies or to individual sectors (such as urban transport in growing cities, see e.g. in [3]), but most of the relevant literature addresses the context of national economies. When used to take into consideration national economic developments, decoupling can still refer to different dimensions:

- Direct consumption of natural resources such as metallic and nonmetallic mineral resources
- Primary energy demand and consumption of fossil fuels
- Greenhouse gas emissions, emissions of pollutants, and generation of wastes
- Parameters of specific interest within a particular context

Quantification of decoupling effects is in general based on referring to the GDP ratio, although the GDP per Capita ratio has been proposed as a reference allowing for better suited estimations; the resulting assessments (at least when considering research results addressing energy) might be less optimistic compared to those based on the GDP ratio approach [4]. Material input per capita and its relation to economic growth is further discussed in literature e.g. by Bringezu et al. [5].

Decoupling strategies need to consider and address the actors in all sectors of the economy, from basic production to decision making (see Fig. 1). Actual implementation of decoupling strategies in practice – and in particular of strategies targeting dematerialization options – will be highly dependent on their adoption in the classical three economic sectors, mainly covering the production and consumption of goods (the Primary, the Secondary and the Tertiary Sector). However, it is the Quaternary and Quinary Sector who will be most influential in setting incentives, initiate changes in existing systems, and reflect on chances and challenges. They are also most relevant when it comes to immaterialization options – and they are highly dependent on intellectual infrastructures including IT and electronic communication devices.

Sustainability of the environmental system depends on existence or creation of a stable balance between various flows of matter, information and energy [6] – which indicates the close dependency of activities in the different sectors of the economy.

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

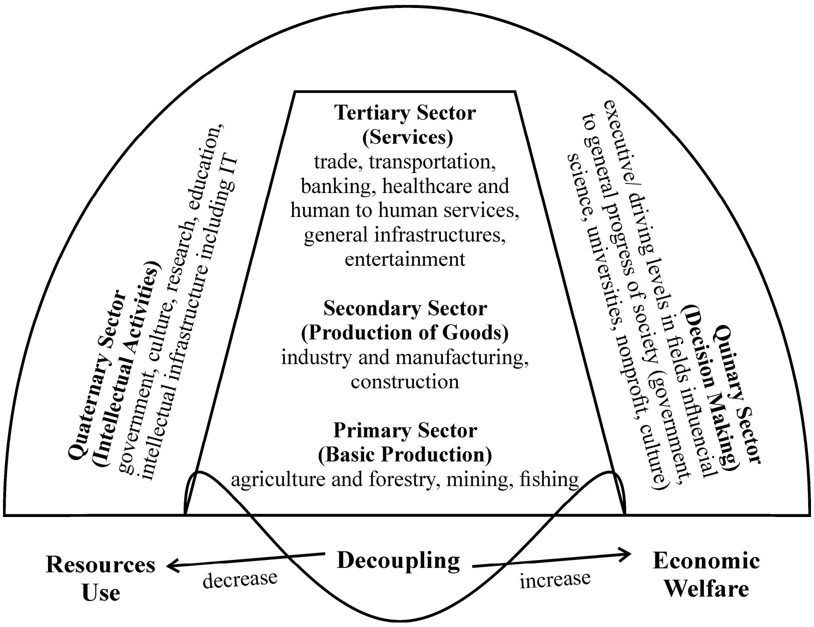

Figure 1. Decoupling economic welfare from resources use as aspired baseline to be implemented in the matrix of the economic sectors

Material use intensity and recycling are expected to be two moderating factors that reduce resources use of rapidly growing economies. Although empirical examples can be found for dematerialization demonstrated for emissions that may be targeted by end-of-pipe technologies, little evidence so far is available for dematerialization in regard to overall material and energy use [7]. In line with this, studies on dematerialization in China, the most populous country in the world, reported limited overall decoupling effects [8], although other assessments indicate decoupling effects particularly for emissions and caused by technological effects in environmental engineering applications [9].

It has been stated with view to energy demand of increasing economies that theoretically 'leapfrogging' to more efficient and cleaner technologies in poorer, developing countries could allow for economic growth without increasing the pressure on the natural environment [10]. However, actual recent developments go into an opposite direction, as economic growth in developing and least developed countries was the main driver for increasing global CO2 emissions [11]. While for the average industrialized country economic growth is found to be partially decoupled from energy consumption and above-average rates of economic growth are accompanied by significantly higher improvements in energy efficiency, in developing countries economic catch-up is typically accompanied by above-average growth of primary energy carriers [11]. This example of energy use patterns in a context of decoupling considerations highlights the necessity to study developments for individual countries in detail. Resources consumption patterns do seem to be characteristic for a certain stage of economic development, and developing countries that have recently caught up economically to the world average have experienced changes in their energy systems that resulted in patterns with environmental impacts comparable to those in industrialized countries [11].

These experiences indicate that additional incentives need to be set by environmental policy or other instruments in order to influence the typical dependencies. Consideration of renewable resources or eco-efficient technologies is not an automatism in developing nations. In the case of renewable energy, it is widely understood that renewable technologies hold potential to promote transition towards a sustainable energy production in developing nations, but actual adoption of renewable technologies is subject to strengthened competiveness, which can include scale and learning effects [12].

It is interesting to note, that although typical resource consumption patterns related to the economic stage of a country have been identified, there might be distinct differences in a specific country. The United States of America, the world's largest economy but also one of the world's largest consumers of natural resources, has experienced an 18-fold increase in material consumption in the period from 1870 to 2005. In contrast to other high-income countries, material use has not stabilized since the 1970 but has continued to grow despite of considerable improvements in material intensity – so no dematerialization at all has happened so far in the country [13]. This phenomenon seems to be linked to historically rooted patterns of agricultural and industrial production, material-intensive infrastructure, and settlement and mobility patterns [13], which indicates that present infrastructures, cultural habits and lifestyles, and management practices can be of long-lasting effects on patterns of resource consumption within a specific economy.

It is further interesting to note that there seem to be fundamental differences on the nature of how individual resources are linked to economic growth and hence can be considered in decoupling strategies. A study on resources use in China and its interlinks to economic developments revealed that consumption of metallic minerals, nonmetallic minerals and fossil fuels grew within positive economic development, while biomass remained stable [8]. Similarly, Steinberger et al. [14] identified that when analyzing material flow data and their links to economic factors, biomass stands significantly out from other main material groups such as ores/industrial minerals, construction minerals, fossil energy carriers – all of which are correlated to each other and to economic activity, but of which none is correlated to biomass. Steinberger et al. [14] further concluded that their results underline the unique status of biomass as the most basic material and pointed out that tendency to use biomass as commercial energy carrier may lead to a closer coupling of biomass use and economic wealth, which could result in increased global inequality.

The economic analyses of a decoupling study conducted in the high-income country Finland, of which one aim was to look more precisely at the structures causing overuse of biomass resources, revealed that the increase in GDP and the ecological footprint related to consumption of biological resources are separated subsystems of the economy [15]. Ecological footprint was found to be increased by the production and consumption of primary commodities, such as wood, paper, fish, crops, animal products and energy and construction, while GDP growth was mainly caused by increased demand in service sectors such as renting and owning apartments, trade and business services as well as governmental services, health, education and social work. According to the results of the study, the two systems overlapped only in few products (dairy, forest) with major influences to both indicators. Eco-efficiency and consumption both increased during the studied time period, resulting in increased overall environmental impacts. Nevertheless, the results of the study might also reflect immaterialization effects.

It is evident that the decoupling subject is also related to the currently vibrant research agenda of degrowth. It has been stated as conclusion from current patterns of economic developments that sustainability and economic growth might potentially be needed understood as being incompatible [16]. However the concept of degrowth is subject to various criticisms both under suitability as target of an economy, and with view to embedded ambiguities [17]. The current EU situation has been found to be in some ways already quite close to an economic system without growth [16]. Not only do mature market economies show indicators with reduced growth rates, but patterns of declining growth rates exist for the world economy – despite rapid growth in emerging market economies such as Brazil, India and China [18]. Exemplary research questions in the field of degrowth contexts address decoupling of jobs from economic growth, the role of social enterprises, and pathways towards achieving sufficiency (rather than efficiency) as an organizing societal principle [19]. But it is also argued that a degrowth target in its basic approach is potentially environmentally ineffective, socially and politically unfeasible, and economically inefficient *(see e.g. [17] and literature cited there, but also see views on the various general approaches in environmental economics along the topic 'To grow or not to grow' as discussed e.g. in [20])*. In addition degrowth seems to be highly susceptible to interpretation problems, as it might be understood as GDP degrowth, consumption degrowth, work-time degrowth, physical degrowth, and other degrowth dimensions [17]. It is understood that the aspects of the degrowth debate are relevant in decoupling scenarios especially when looking at perspectives of immaterialization targets, but the partially controversial views on degrowth are not substantially relevant for the key aspects of this study and are therefore not further discussed in this publication.

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 [21]. This includes several types of equipment such as: televisions, refrigerators, freezers, washing machines, cloth dryers, air conditioners, personal computers and monitors.

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 [23] *(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 [24] *(citing abovementioned UNEP report as well)*. These amounts represent one to three percent of global municipal waste production *(see [25], with reference to further literature)*.

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 programs. This typically results in recycling of e-waste with recovery of a limited number of metals [22].

Most developed countries and some developing countries such as South Africa, India, China, Cambodia, Malaysia and Thailand have developed national legislations and policies specifically for management of WEEE [25].

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 [26]. 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.

In line with the underlying strategies for increased sustainability, 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 [27]. There is a general shift of natural resource extraction away from industrialized countries towards other resource-rich regions in the world, which results in increasing dependency on imports [28]. This indicates the strategic importance of availability of metal resources for industrial activity in Europe – and elsewhere.

The global demand of metal resources is increasing rapidly. Forecasts indicate that the overall consumption of metals in the year 2050 will be five times greater than the current levels, mainly due to huge demands in in developing BRIC countries, and that global demand for metals such as Au, Ag, Cu, Ni, Sn, Zn, Pb and Sb is expected to be several times greater than the amount of their respective reserves [29]. The amounts of rare metals present in WEEE are relatively high with respect to the worldwide demand [27] – 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) [27]. 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 of 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 [30]. 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 [31]. Today mobile phones have become the most ubiquitous electronic product worldwide [32].

Voluntary take back networks can significantly increase collection rates for specifically targeted waste electronic equipment. Suitable voluntary or other take back networks for mobile phones can therefore vitally contribute to tackle the increasing shortage of key metals typically found in mobile phones [32].

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) [33].

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. [24]). 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 [34]. 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 [22] 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. CASE STUDY: 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 an earlier study looking at high-grade WEEE (results of the study have been presented by authors of this publication as a conference contribution [35]). In order to estimate the amounts of precious metals contained in the two types of electronic communication equipment, the assessment used data published by UMICORE [36]. The study is based on global sales data for the year 2007, and the respective amounts were taken as static parameter; in this approach it is assumed that each sold unit will finally result into a waste unit.

This section first summarizes the findings on mobile phones and computers in order to highlight the respective possible amounts of potentially recoverable precious metals. This is followed by an assessment of the economic value of the studied materials.

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 potentially recoverable amounts for the selected five precious metals are shown in Fig. 2 and Fig. 3.

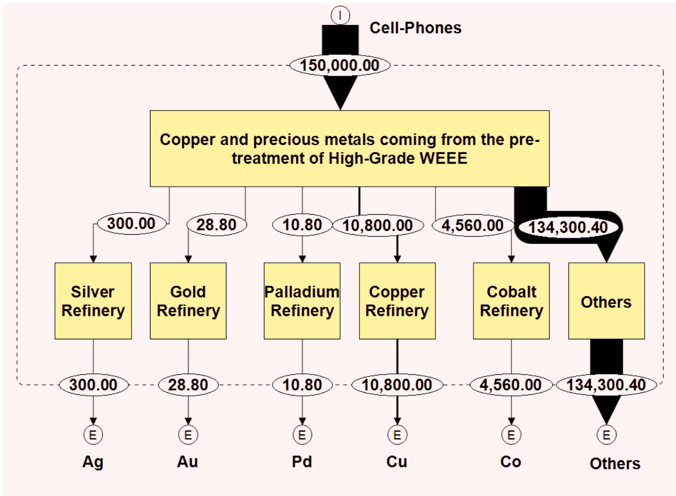

Figure 2. Schematic diagram of global potential recovery of five selected precious metals (Ag, Au, Pd, Cu, Co) from mobile phones (values are reported in Mg/a) [35]

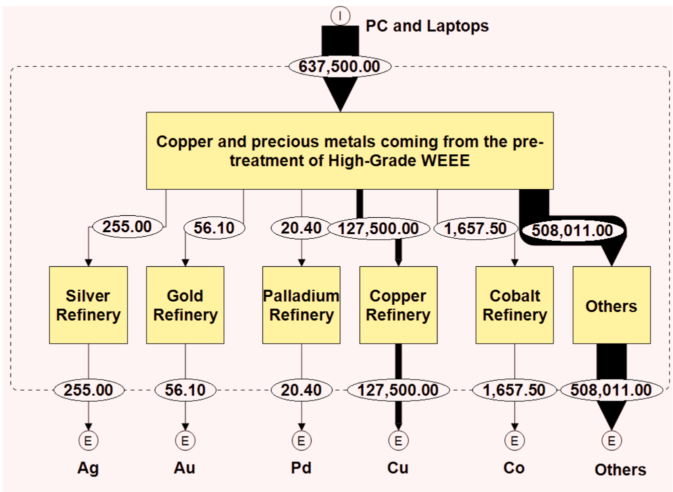

Figure 3. Schematic diagram of global potential recovery of five selected precious metals (Ag, Au, Pd, Cu, Co) from PCs/ Laptops (values are reported in Mg/a) [35]

The potential mass flows of recovery of the five precious metals from mobile phones and PCs/Laptops put in the market in 2007 are summarized in Table 1 and Table 2, along with an estimation of the value of recovery in million $. All prices refer to the year 2011 and represent the resulting USA market price (London Metal Exchange in the case of Cu and Co) (as published by the U.S. Department of Interior [37]).

The case 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.

The data are in good agreement with results of research carried out by Chancerel & Rotter [38] [39], who quantified that mobile phones contain less than 0.01% gold, but assessed that over 50% of the economic value of the materials results from this gold content.

TABLE I. AMOUNTS AND VALUE OF POTENTIALLY RECOVERABLE PRECIOUS METALS FROM MOBILE PHONES (BASED ON U.S. MARKET PRICES FOR THE YEAR 2011)

Metal	Potential recovery	Price [37]	Value of potential recovery
	Mg/a	*$/kg*	*Million $*
Ag	300	1,137	341.1
Au	28.8	50,541	1455.6
Pd	10.8	23,744	256.4
Cu	10,800	8	86.4
Co	4,560	32	145.9

TABLE II. AMOUNTS AND VALUE OF POTENTIALLY RECOVERABLE PRECIOUS METALS FROM PCS AND LAPTOPS (BASED ON U.S. MARKET PRICES FOR THE YEAR 2011)

Metal	Potential recovery	Price [37]	Value of potential recovery
	Mg/a	*$/kg*	*Million $*
Ag	255	1,137	289.9
Au	56.1	50,541	2835.4
Pd	20.4	23,744	484.4
Cu	127,500	8	1020.0
Co	1,657.5	32	53.0

As the demand of industry for precious metals is high and their availability is crucial for industrial activities, they become a prerequisite for positive performance of economies. Manufacturing of electric and electronic equipment covers a prominent position in such activities. When looking at the USA as an example, it becomes obvious that this market sector is of significant economic relevance: in 2012, the share of use for manufacturing of EEE was 35% for silver, 5% for gold and 23% for copper [37].

In order to better understand the interdependencies between economic growth, management of EEE and occurrence of WEEE, it would be essential to carry out more detailed studies. Among others, it would be necessary to take into consideration the amounts of electronic equipment as dynamic parameter over time, and to close the gaps of knowledge on quantitative and qualitative material flows occurring in different regions of the world.

However, the results of this case 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: EXEMPLARY ASSESSMENTS UNDER SPECIAL CONSIDERATION OF ASPECTS RELEVANT TO THE CASE OF JORDAN

The level of awareness and reaction on the waste generated from electric and electronic equipment differs significantly between developed and developing countries. Many developing countries are facing huge challenges in managing WEEE which are either internally generated with increasing rates due to high demand for electronic items or which are imported illegally as 'used' goods. In such countries, WEEE typically makes up around one per cent of the total solid waste [25].

Jordan is one example of a developing country where it has been recognized that evaluation of consumption patterns along with increasing the level of awareness on WEEE are central questions [40]. Jordan is considered a low-middle income country. It is characterized by a fast increase of its population and a high rate of economic growth. The current economic development is closely linked to developments in the industrial sector [41]. As one consequence, demand for resources is rapidly increasing.

Decoupling waste generation from economic growth and putting WEEE recycling in practice in a country like Jordan would require the following actions (also see [35]):

(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 an adapted decoupling strategy

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

To manage electronic waste in a sustainable way, it is essential that well elaborated government procedures are in place in order to establish effective legal and managerial frameworks. Policy enhancement strategies need to consider the complexity of the topic in addition to the specific situation in a country and already available structures.

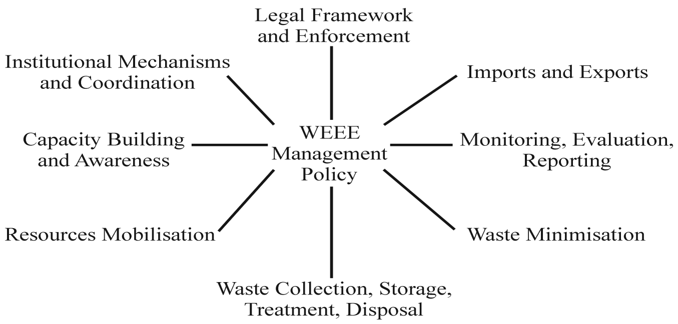

Figure 4. Elements of WEEE management policy in compliance with provisions of the Basel Convention (based on [25])

Fig. 4 visualizes the necessary elements of an electric and electronic waste management policy to be developed in compliance with provisions of the Basel Convention in order to manage EEEs in a sustainable manner throughout their life cycles (here based on a case study looking at the example of the country Sri Lanka). Eight statements are contained in the concept, they relate to (1) existing import/ export procedures, (2) WEEE minimization, (3) collection/ storage/ treatment and disposal, (4) legislative frameworks, (5) awareness on WEEE, (6) implementation and coordination of institutional mechanisms, (7) monitoring, evaluating and reporting procedures of management systems, and (8) means for mobilization of national resources for e-waste management [25].

Implementation of concepts such as IPR (Individual Producer Responsibility) can create incentives to increased recycling activities and to achieve better recyclability of electric and electronic equipment. Experiences from IPR schemes under the German WEEE legislation indicate that established individual characteristics of existing systems have a decisive influence on actual efficiency [42].

Aside from establishing the necessary legislative and general managerial frameworks, the availability of technical solutions for WEEE recycling will be a pressing challenge for all countries.

It is particularly difficult to channelize small electric and electronic equipment into efficient collection and treatment schemes. Despite of the existence of infrastructure in the USA and in Germany, the actual recovery rates for gold are below 10% for mobile phones, whereas around 40% of the gold contained in end-of-life desktop computers was recovered in 2007 [38] [39]. Aside from losses due to disposal of small equipment together with residual waste, significant losses occur during pre-processing of the WEEE, where large fractions are dispersed over the various output streams [24] [43]. In electronic equipment, precious metals are closely connected to other metals or are used in complex material mixtures - which is a high challenge that requires special attention, refined engineering skills and innovation capabilities when it comes to recycling. Tendencies to reduce size of electronic devices results in higher complexity of such equipment, which increases further the level of difficulty in recycling.

VII. Conclusions

Natural resources use is on the top of the environmental policy agenda in many countries around the world and under a global perspective. 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 are 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. However, high grade WEEE is a highly challenging area in waste management and treatment as there is a lack of data on amounts and composition of different EEE devices in different countries. Recovery of materials contained in electronic communication devices represents a high potential economic value of potential recovery, which includes small equipment such as mobile phones. Collection and treatment of small electric and electronic equipment is a particularly challenging, but at the same time highly promising field.

Favorable 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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