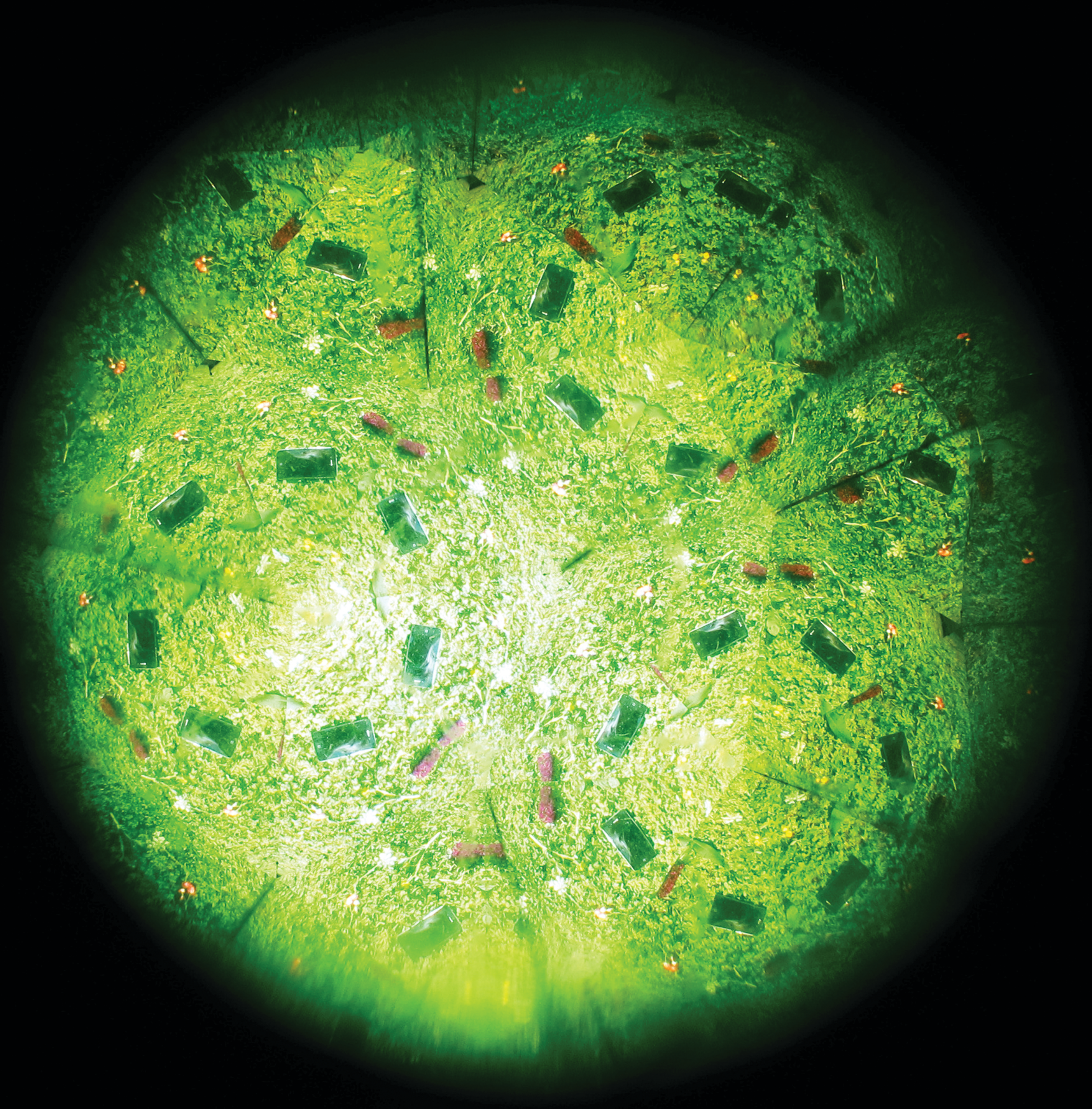
Finding the Transition Path Towards Circular & Sustainable Systems for ICT Products

- An analysis on how Deposit & Refund and End-of-Life Management Systems could be initiated to close the loop around finite resources for the future



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Abstract

This study investigates how new system initiatives around *deposit-refund systems* (DRS) and *end-of-life management* (EoLM) could merge and possibly lead to a circular and sustainable transition path of metal resources embedded in information and communications technology (ICT) products. Seen through the object of mobile phones, the cardinal objective has been to find ways of approaching full recycling and recovery of the finite metals and to see how these could be cycled back into the supply chain. In this way, bypassing environmental and social externalities in the pre-manufacturing phase from the use of virgin resources.

Inspired by the transformative approach in backcasting methodology, this study builds a vision for a sustainable future of ICT products, by analyzing approaches to circular economy (Boulding) (Stahel) and how it conforms to the sustainability approach in environmental and ecological economics respectively. This vision is used to make a sustainable gap analysis of the present post-commercialisation ICT product life cycle, and to define a set of goals along information transfer, resource and value transfer and needs of technological innovation, for increased recycling and recovery of metals. This leads up to a scenario analysis for a DRS on mobile phones and the search for new opportunities in EoLM. Empirical studies for the analysis are based on a larger consumer survey around mobile phones and formal semi-structured interviews of individuals in relation to the present collection, pre-processing and end-processing stages of e-waste.

The main conclusion is that a DRS system is deemed able to create a solid foundation for effective end-collection throughout the post-commercialization product life cycle and is able to transfer valuable resources and information to the EoL phase. EoLM can ensure better recovery if original equipment manufactures (OEMs) engage by using the opportunities of reversed logistics and sub-contracting the scrap-resource to end-processors. Here, there is a need to certify the processing of e-waste and to provide eco-rating systems of products, to ensure sustainability in the system and provide measurable and transparent lifecycle product profiles in the future. If such system initiatives are broadly adopted, the analysis shows that needed technological eco-innovation of products could emerge as a result of efficient collection, symbiotic network possibilities in EoL and possible push-effects from political consumers.

Therefore, this study contributes to the planning field of sustainable production and consumption systems by qualifying a combined scenario on how to design and approach the opportunities in DRS and EoLM.

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Table of Content

Figures & Tables

Abbreviations

AMOLED – *Active-Matrix Organic Light-Emitting Diode*
BC – *Backcasting*
B2B – *Business to Business*
BFE – *The Danish Consumer Electronics Association*
CC - *Creative Commons*
CE – *Consumer Electronics*
CEA - *Consumer Electronics Association*
CLP - *Closed-Loop Production*
CRO - *Collection and Recycle Organization*
C2C – *Cradle-to-Cradle*
DEFRA – *UK Department for Environment, Food and Rural Affairs*
DfD – *Design for Disassembly*
DfES – *Design for Environment & Sustainability*
DfX – *Design for X*
DPA-System – *Danish Producer Responsibility - System*
DRS *Deposit & Refund System*
DST – *Statistics Denmark (Danmarks Statistik)*
EC – *European Commission*
EEB - *European Environmental Bureau*
EEE - *Electric and Electronic Equipment*
EICC - *Electronic Industry Citizenship Coalition*
EMF – *The Ellen MacArthur Foundation*
EoL – *End of Life*
EoLM *End of Life Management*
EP – *European Parliament*
EPA – *Environmental Protection Agency - as in the Danish EPA – Miljøstyrelsen (MST)*
EPR – *Extended Producer Responsibility*
ERP - *European Recycling Platform*
EU – *European Union*
EuP - *Energy-using product*
EVDs - *Electronic Visual Displays*
FDPs – *Flat Panel Displays*
GeSI - *Global e-Sustainability Initiative*
GHGe – *Green-House Gas emissions*
GPWM - *Global Partnership on Waste Management*
ICT – *Information and Communication Technologies*
IE - *Industrial Ecology*
ITO – *Indium-Tin-Oxide*
ITU – *International Telecommunications Union*
LCDs – *Liquid Crystal Displays*
LED – *Light emitting diode*
Li-ion – *Lithium-ion Batteries*
LME – *London Metals Exchange*
MEC – *Marginal External Costs*
MEX – *Marginal Extraction Costs*
MFA – *Material flow Accounting*
MNO – *Mobile Network Operator*
MOSFET – *Metal-Oxide Semiconductor Field-Effect Transistors*
NiMH – *Nickel–Metal Hydride Batteries*
OEM – *Original Equipment Manufacturer*
OFET – *Organic Field Effect Transistors*
OLED – *Organic Light Emitting Diodes*
OPV – *Organic Photovoltaics (organic solar cells)*
PCB – *Printed Circuit Boards*
PGMs – *Platinum Group Metals*
PM – *Precious Metals*
PSS – *Product Service Systems*
PV – *Photovoltaics (Solar Cells)*
RC – *Recycling Company*
R&D – *Research & Development*
REE – *Rare Earth Elements*
RMI – *Raw Materials Initiative (The European)*
RoHS - *Restriction of Hazardous Substances*
SBM – *Sustainable Business Model*
SCP – *Sustainable Consumption and Production*
SD – *Sustainable Development*
SDD – *Solid-State Drives*
SS – *Strong Sustainability*
TBS – *Take-Back Systems*
UNCTAD – *United Nations Conference on Trade and Development*
UNEP – *Untied Nations Environmental Program*
UNIDO – *United Nations Industrial Development Organization*
WEEE – *Waste of Electric and Electronic Equipment*
WS – *Weak Sustainability*

Measurements / Amounts:
b - Billion
Bn - billion
Bt - gigatonnes
g - grams
g/t - grams per tonne
kWh – kilowatt hour
mg - milligrams
m – million
mt – million tonnes
ppm - parts per million
t - tonne
t/yr - tonnes per year

Currencies[1]
DKK (Danish Kroner)
EUR (Euro)
USD (American dollars)

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[1] Monetary values in this report are based on an exchange rate where: 100 DKK = 745 EUR, and 100 EUR = 130 USD, in correlation with average currency rates in 2013. All included values are given as estimates.

1. Introduction

Sustainable development in the 21st century, or the transition to a sustainable society[2], has become a systemic challenge with economic, social and environmental dimensions on equal footing (UNEP, 2013: 3). This is for an example expressed by the exponential use of finite natural resources from 1900-2005, which today range above an immense 30 Bt of ore and industrial minerals alone (Krausmann, et al., 2009: 2699).

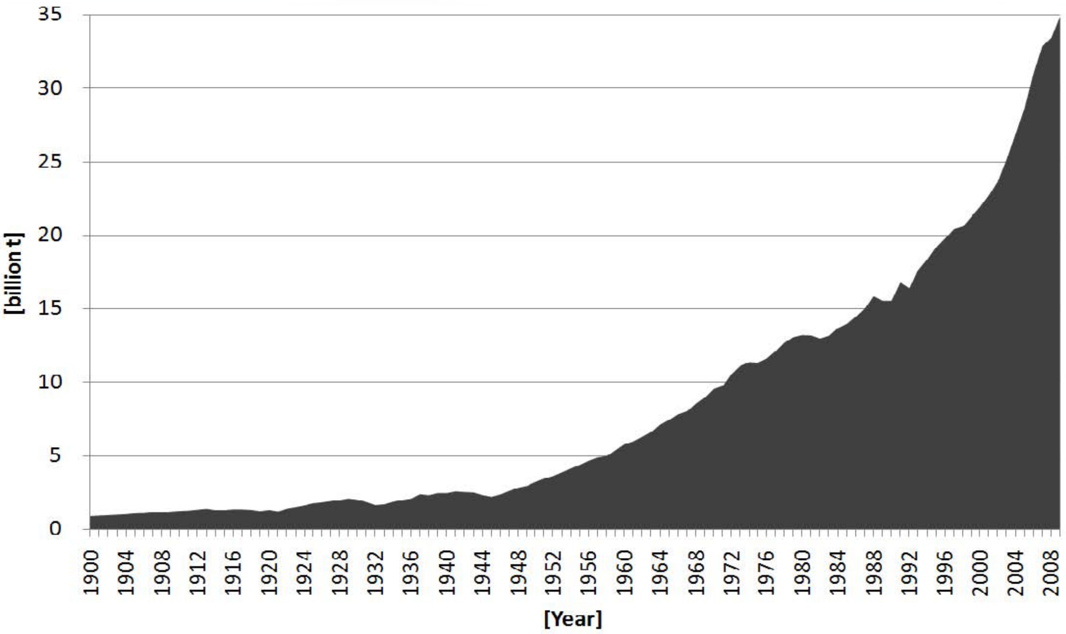

Figure 1: '*Global Extraction of Metallic & Industrial Minerals in Bt from 1900–2005'*. Illustration reprinted, courtesy of SRU (2012:5). Original source: Krausmann et al. (2009: 2699).

This kind of resource use naturally creates large flows of matter and one of the fastest growing types from today's society is from the electronic sphere (Widmer, et al. 2005: 435). The global generation of electronic waste (e-waste) has been estimated to be somewhere in between 20-50 million tonnes (mt) per year (Robinson, B.H. 2009: [185] 3). In Europe alone, the creation of e-waste is estimated around 9mt annually, growing to 12.3mt/yr in 2020 (Meskers, et al., 2009: 4) and maybe more (Appendix 3A). Moreover, UNEP states that 70% of all collected e-waste in developed countries ends up in unreported and largely unknown destinations. This means that some unknown amount of natural resources are lost, while also creating massive health and environmental consequences around the world due to contaminants and air emissions in the end-of-life (EoL) phase (UNIDO, 2012: 1). Additionally, vast environmental and social impacts, all the way back to the extraction of the finite raw materials, are found embedded in the pre-manufacturing of electronics (See Appendix 3D).

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[2] As re-stated in the UNCSD Rio+20 outcome document: "The Future We Want" (2012)

One important and fundamental obstacle to solving the e-waste problem has been outspoken as the linear focus in the economy. Traditional economic thinking is often defined by the linear "take-make-waste" pattern, where the opposite is a circular and regenerative system around resources (EMF, 2013: 14f). The linear path for most product lives goes from extracting some natural resource and then reshaping and converting it into a technical resource that can fit parts of a product. When the whole product one day becomes obsolete, after end-use, it goes back to nature as waste (ibid.). Therefore, the complexity of converted natural capital in the design and manufacturing phases makes waste a problem in general, since nature has to absorb this matter again. The higher the complexity of elements in our products, the harder it is to see this matter entering biological systems or technically becoming new products. Therefore, processing our wastes is the option we have to help the natural cycle, which we do to some extent.

Therefore, for true recycling of natural resources, the task is to turn disorder into order as much as possible. In a linear system, high-value natural capital ends up as low-value waste (e.g. as maybe heat and residues), which logically contradicts the natural cycles. Technically speaking, minerals and metals embedded in electronic products are not consumed; they are only transferred between the lithosphere and the techno-sphere. Theoretically, increasing our recycling capabilities would thereby make these resources "*renewable"* (Hagelüken, 2012: 199). This is why we must seek to develop a cyclical production and consumption system – what in recent years has been publicized as the transition towards a circular economy (EMF, 2013).

Therefore, this circular idea clearly holds both a change in the way we produce and the way we consume things. Therefore, the grounding thought behind this study evolves around what that '*desirable change*' actually is and, more importantly, what it implies and how we can adopt it.

1.1 Closing in on ICT

In this techno-sphere of electronics, *'Information and Communication Technologies'* (ICT) are generally viewed as the means to a new industrial paradigm - the foundation of promising development of *'the information society'* (Hanna, 2010: 27). This development is also seen as the early stage of an so-called *ICT revolution* (Hanna, 2010) where markets are growing fast (Appendix 2F). In a techno-optimistic point of view, Chui et al. explains how ICT promises to create new business models, improve business processes and reduces costs and risks in almost any manner (Chui, et al., 2010: 1).

An official definition of ICT is expressed as: "ICT products must primarily be intended to fulfill or enable the function of information processing and communication by electronic means, including transmission and display" (UNCTAD, 2011: 2). Thus, meaning that an ICT device somehow enables the user to access, store, transmit or manipulate information – often to use this information for communicating with or to other individuals. Some other definitions refer to audio-visual, telecommunication or computer networks. Therefore devices like; 'mobile phones, mp3-players, tablets and notebook computers are examples of such technologies'.

However, ICT is today the third largest e-waste category[3] here in Denmark and in Europe and growing as well (cf. section 5.1)(Appendix 2F). However, sustainable development can not only view ICT as one of the most recognizable e-waste categories of the present time, it must also address this progressing deep integration with human life as a possible evermore disruptive factor to natural resources in the future (Appendix 2G). With these arguments in mind it is possible to target ICT as one of, if not the most, important and interesting e-waste categories of today. Other features such as the high value metal resource content of ICT, the high design complexity of these products and low collection rates (especially for small devices) are also evident reasons for focusing on this category (cf. section 5.2-5.3)(Appendix 3B). Here, mobile phones have significantly poor collection rates compared to the millions that are put to market every year (cf. section 5.1.1). Approaching sustainable management of minerals and metals, for full recycling and recovery, has become difficult with the elements' complexities in these products and their interaction with EoL systems, so: "*We need to change the whole mindset on recycling of metals, moving away from a Material-Centric approach to a Product-Centric approach"* (UNEP, 2013: 3). Therefore, as the technical objective behind this study and way to assess the circular economy approach as the means to reach sustainable development, ICT would show as a valuable agent for this desired change.

1.2 Systemic Problems

In the 1990s we saw the arrival of Extended Producer Responsibility (EPR) in Europe, to move increasing costs and burdens from taxpayer-funded waste treatment to the producers. The EPR principle was introduced simply to: *"Relieve municipalities of some of the financial burden of waste management and to provide incentives for producers to reduce the use of primary resources, promote the use of more secondary materials, and undertake product design changes to reduce waste"* (Cahill, et al. 2010: 455).

The WEEE Directive, first introduced in 2002 (Directive 2002/96/EC), was created to charge manufacturers and importers that place electric and electronic equipment (EEE) on the European market for taking their products back and to ensure that they were disposed of through environmentally friendly methods. The aim was to minimize WEEE (Waste of EEE) and to increase reuse, recycling and recovery of materials (ibid.)[4]. So, by putting the responsibility on producers it should, as a result, close the circle and promote innovation in the product design. However, it can thus be questioned if the degree of reprocessing for recycling and recovery also

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[3] The European regulation on *waste of electrical and electronic equipment (*WEEE) Directive (2012/19/EU) is arranged in ten different categories, amended as Annex I, reflecting the way e-waste is being categorized, collected and finally estimated across Europe. ICT is viewed as category 3: *1) Large household appliances 2) Small household appliances* ***3) IT and telecommunications equipment*** *4) Consumer equipment 5) Lighting equipment 6) Electrical and electronic tools 7) Toys, leisure and sports equipment 8) Medical devices 9) Monitoring and control instruments 10) Automatic dispensers*

[4] In addition, the RoHS Directive (2002/95/EC) was introduced in 2002 to reduce and phase out hazardous substances: lead, cadmium, mercury, hexavalent chromium and two brominated flame retardants, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDEs). Likewise, the EuP Directive (2005/32/EC) was introduced in 2005, which sets minimum standards for energy efficiency in energy-using products.

is a matter of the starting point: around collection, the involvement of manufactures and development in product designs.

In this light, the current WEEE regulation does not *directly* force *original equipment manufactures* (OEMs), which are often viewed as producers, to manage their products. It places responsibility on *producers or importers* of EEE to manage what quantity (in tonnes) they placed on the European market. Hereby, so-called producers or importers are encouraged to organize around collective collection schemes, or Collection and Recycle Organizations (CROs), which they pay fees to for the management of their e-waste. This is done through schemes on a 'pay-as-u-sell' or a 'pay-as-u-scrap' deal (The Danish EPA, 2012: 26). So in principle, the current WEEE regulation system is promoting a service industry "downstream", but decreasing the waste burden for manufactures and importers of electronics through simple payment by fees, mostly controlled through the collective schemes. This seemingly creates a problem. OEMs do not come to work with the actual technical flow of resources and so real cooperation with the recycling industry could seem partially bypassed. End-of-Life (EoL) management is not done by the OEMs, but by organisations they pay to do so, which only can be expected to fulfil their relatively simple mandate. The hypothesis is thus; that OEM's are so far from what actually happens in the processing of the e-waste, so the incentives from this regulation to optimize design for better recycling, innovate materials use and so forth, are very few if existing at all.

In correlation with these assumptions, a study by Smith (2012) concluded that, even though the WEEE-directive has created a system that forces partial recycling of materials entering the system, it does not give economic incentives for innovation and designs that consider recycling or complete collection of e-waste. The establishment of economic incentives, both for businesses and consumers, is crucial for reaching the noble and sustainable goals behind the WEEE-directive (Smith, M. 2012: 79f). Building upon Smith's research, this study aims at 'visualizing' and 'finding' these incentives.

Almost every inch of electronic products is made up of finite natural resources (Ongondo et al., 2011), meaning that crucial metal and other raw materials eventually will end up as e-waste, if not initialized. Setting current recycling and processing of e-waste aside, it is presumed that the extractions of the relative abundant metal resources in earth's crust will gradually become increasingly scarce and costly in any future scenario. Here there is clear indicators of this scarcity problem are found evident today (cf. section 3.2.2).

The issue is then to find beneficial ways of collecting and managing these electronic items throughout the EoL phase. We also need new systemic models that can drive the sustainability incentives – to design of products for recycling and recovery of finite natural resources and with no harm to the environment. This is, to making design and content, the key in obtaining resources in a circular flow (EMF, 2013: 23). Instead of business models where the OEMs have an indirect relation to the EoL phase, for instance through CROs, greater management of the EoL phase could in turn create a sustainable and cost-efficient path for business (GeSI, 2008: 18). This means that OEMs could look at the recovery of metals as a way to maybe protect their business against disruptive and volatile metal markets. However, this does not mean that e.g. the CROs should be left out in the future, but that they, for example, could have a way more progressive role than today. Therefore, to find this path we must look at the specific sustainable gaps in the post-commercialisation phase of an ICT product life and so how these resources can end up being cycled back to the manufacturing stage.

1.3 Identified Initiatives for a Circular Path

A screening study from The Danish Environmental Protection Agency (EPA) was carried out in 2012 (environmental report nr. 1449). The overall objective of that study was to find feaseable incentives to promote *environmentally friendly design of electronic equipment* (The Danish EPA, 2012: 5)[5]. In the background materials for the Danish EPA environmental report, 19 iniatives for business and regulation were screened for effect on environmental friendly product design and valued for costs and benefits through three workshops with various stakeholders in the general EEE life cycle. Nine iniatives were finally recommended as the most promising options (See The Danish EPA, 2012: 7). However, two of the options that was recommended, were to establish a *Deposit and Refund on Small EEE* and to promote a *Network for producers and recyclers.* These areas could then be seen as ways to establish efficient collection and secondly enable the OEMs to manage and work with recyclers to recover resources again and supply secondary raw materials for product manufacturing. Deposit and refund systems (DRS) has in other areas e.g. on beverage containers, shown to be very effective collection systems (DØR, 2013: 282). Also, a general extended focus on opportunities in the EoL phase has been widely recommended as a solution to the e-waste problem by the Global e-Sustainability Initiative (GeSI) advocating for a general larger focus by the industry on *EoL-management* (GeSI, 2009: 7). Therefore, it seems as if there is a good foundation for looking more into how such scenarios could play out in reality – thus how these system initiatives could be embedded in society and business models for the future.

1.4 Problem Scope

Immense consumption of finite natural resources, such as metals, is a main challenge now and in the future. Challenging the linear productions and consumptions system in today's society, with the idea of a circular economy show to be a promising approach coping with the need of sustainable development. Electronic waste is one of the fastest growing waste streams in society today, having great impacts on environment and society and rely heavily on finite mineral and metal resources. ICT products both show to be a driving the development of the information society and at the same time has a huge stake in the growing e-waste generation - a maybe true paradox. To adopt circular flows of resources in the economy, new approaches to reconnect the design and manufacturing phase with the EoL phase in product life cycles, must be designed and developed. In light of these reflections, the main objective of this study is to design and create a framework of sustainable pathways around the post-commercialisation life cycle of ICT products. Mobile- and smartphones have shown to be a great challenge to the resource and e-waste situation on various levels, why they will provide a suitable research example for the further analysis and bridge to the rest of the ICT category. In relation to the vision of a circular

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[5] In the background for this study, and other EU related studies on environmnetal friendly design of electronic equipment, is the recognition of the European Environmental Bureau's (EEB) calculation that some 80% of the environmnetal impact from EEE could be avoided in the design phase of such (EEB, 2010: 5)

economy, new solutions are suggested to reach the goal of a sustainable future, but design and development of these system initiatives, defined as; *'Deposit & Refund Systems' (DRS) and EoL management (EoLM),* is obviously needed today. Therefore, the questions that is sought to be answer in this study is defined as followed:

Problem Formulation:
'How can new system initiatives for DRS and EoLM[6] be designed and applied to the post-commercialisation life cycle around ICT products, contributing to a circular and sustainable production and consumption system, assessed through mobile phones, to approach full recycling and recovery of finite metal resources?'

Analytical Questions:
Five questions have been submitted to guide the analytical flow of the study. This study was build upon a *backcasting methodology* which prescribes the initial step of creating a vision for the future, and then through a sustainable gap analysis of identifying problems in the present production and consumption system, finding specific (sustainability) goals for the future. This enables the researcher to design different scenarios and work towards the vision. Examination and finally discussion on how a DRS and EoLM scenarios play out individually and in combination, is then analysed for meeting goals and the larger vision[7]. Five questions have been assembled as the aggregated analytical scope for the chapters 3-7 and are as follows:

Ch. 3: *'What is behind the idea of a circular economy and how does it conform with sustainability?'*
Ch. 4: *'What would a vision and its objectives look like, established upon circular flows of metal resource, in the ICT sphere?'*
CH. 5: '*What are the sustainable gaps in the present post-commercialisation phase around ICT products, which sustainability goals should be established upon?'*
Ch. 6: *'How can the scenarios for DRS and EoLM be designed and applied to ICT products as seen through the example of mobile phones?'*
Ch. 7: '*Which impacts can be expected from DRS and EoLM scenario initiatives evaluated through the sustainability goals, and how does these findings correspond with the overall vision and objective?'*

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[6] Deposit & Refund Systems (DRS) and End-of-Life Management (EoLM)

[7] The methodological approach of backcasting, used for this study is further described in section 2.2.

1.5 Project Design

In this introduction, *chapter 1*, the overall problem scope of finding sustainable gaps in the post-commercialisation ICT product life cycle and applying new initiatives of circular approaches to solve the sustainability problems, should now have been carefully outlined. Next, in *chapter 2,* the background for the methodology, which supports the analysis, will be discussed and defined. Since this study works around some major environmental and social issues concerning e-waste and resource use, a delineation of the scope has been provided in the start of this chapter. Afterwards, the backcasting method, which has been used to build the analysis structure, will be more carefully outlined and defined. Furthermore the empirical work and sampling, used in this study, will be described. The analytical body of this study is found in *chapters 3-7* (marked blue in figure 2), and is further described in section 2.3.

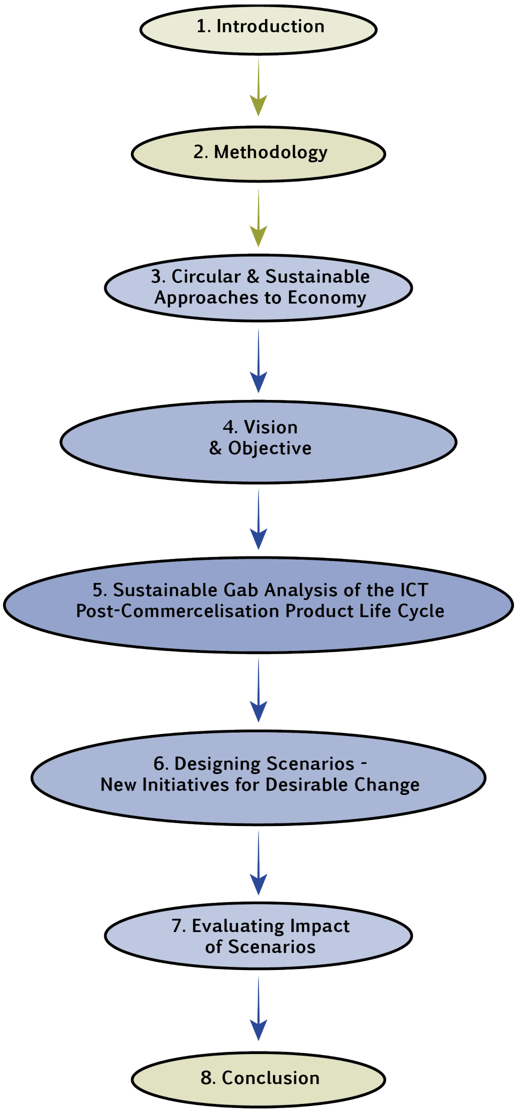

Figure 2: *'Project Design'*. Vestergaard (2013)

2. Methodology

In this chapter the methodological choices behind this study will be described and evaluated. Firstly, disposition and delineation of the study has been provided, for the ability to distinguish between choices, capabilities and limits to the analysis. The second aim is to explain why and how *backcasting* has been chosen as the analytical approach and how it is incorporated in the final analytical design. Thirdly, after a short description of applied theory, empirical studies and sampling as inputs for the analysis will be described.

2.1 Delineation of the Study

This study generally has a system focus that can be justified from the base of the problem scope - searching for qualified ideas on how to organize circular and sustainable systems around ICT products - combatting waste to society and extensive use of exhaustible natural resources. This e-waste can be regarded as product-fixed resources that, if systematized, can be sent back as feed-in materials for new products. Here, problems today seem to originate from the current institutionalized settings regarding managing and controlling flows of electronic waste (cf. section 1.2).

ICT products are the main object of study for various reasons such as the large resource content (or added resource value) they posses, their technological complexity, socio-technical importance and volume in the WEEE mix (cf. section 1.1 & 5.2). In addition, mobile phones (from now on including both feature phones and smartphones) have become the case focus object, for which initiatives and opportunities for desirable change should be found. The reason is that mobile phones have a special place in society today as an immense social-technical value and at the same time, have one of the highest valuable resources concentration compared to volume and weight, along with huge collection problems in the EoL phase while also being one of the most widespread ICT products overall (cf. section 5.1.1 & 5.3+Appendix 2F). The idea of using mobile phones as the single focus object would be able to generate more comparable knowledge, than focusing on several ICT products at once. Technologically mobile phones, and for instance tablet computers, are not remarkably differentiated (cf. section 5.3), which is why they are often also seen as a cluster of objects. As electronics are both distributed through retail and wholesale channels to end-users, it was necessary to keep a stronger focus on a single market – and since private consumers produce the largest amount of electronic waste (cf. section 5.1), the private retail market was targeted.

Metals are at the core of electronics manufacturing (cf. section 1.1+5.3), and therefore the primary focus, and is why other resources such as plastics, ceramics and glass that ICT products also consist of, are viewed secondary to this study. That leads to another delineation point of the study scope, concerning a secondary focus to a more in depth analysis of the ecological footprints - e.g. GHGe, waste water or chemical pollution from extraction and mining of virgin minerals, shipping and distribution of products and components, manufacture and end-use. The reason is that some of those evident externalities will be largely *bypassed* in the course of the possible increase in recycling and recovery of metals. Such externalities will not necessary be fully eradicated, but for instance some ¾ of GHGe is found in the pre- and end manufacturing stages of mobile phone life cycle (cf. section 5.3.5). Increasing the recycling of materials into new products is thus believed to contribute directly to combat these externalities.

Moreover, energy efficiency is found as a main focus for practically all OEMs of ICT, and a fundamental R&D area in their strategies for product development and CSR policies respectively. Here, the Eco-design Directive (2009/125/EC) seems sufficient to control energy-use of new products and future strengthening of energy-efficiency requirements on marketized ICT in the EU. In addition, this directive also seems to raise the bar on a global level as well (cf. section 5.3.5).

Another secondary focus works around hazardous (or harmfull) substances such as heavy metals, flame retardents and radioactive substances, which can play a large part in emissions to e.g. soil, water and obvious human health, throughout the full product lifecycle. Again it can seem insufficient when focusing on sustainability, not to address all the environmental and social concearns. But it is thus believed that a continual strengthnening of e.g. the RoHS directive (2011/65/EU)[8] and sciencetific reviews of new possible harmfull substances, will be sufficient to eradicate the use of the most problematic ones along with approaching more circular patterns around metal resources.

In connection to the problem formulation and how new initiatives correspond with the circular and sustainability dimension of the study scope (cf. section 1.5), it should now be clear that ways to create reversed metal flows of the resources fixed in ICT products today are of the primary focus. The *red frame,* following in figure 3 below indicates the post-commercialisation phase of a product life cycle and is chosen as the main study scope. This is also where the selected initiatives should be organized and arranged. Qualified action around initiatives in this phase of a product life is thus believed to be able to impact flows in the pre-commercialisation phase selected under the *green frame*.

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[8] The RoHS directive continue to combat lead, mercury, cadmium, hexavalent chromium and the flame retardants Polybrominated biphenyls (PBB) and Polybrominated diphenyl ethers (PBDE) by banning theses substances within maximum concentration values – see Annex II to the directive).

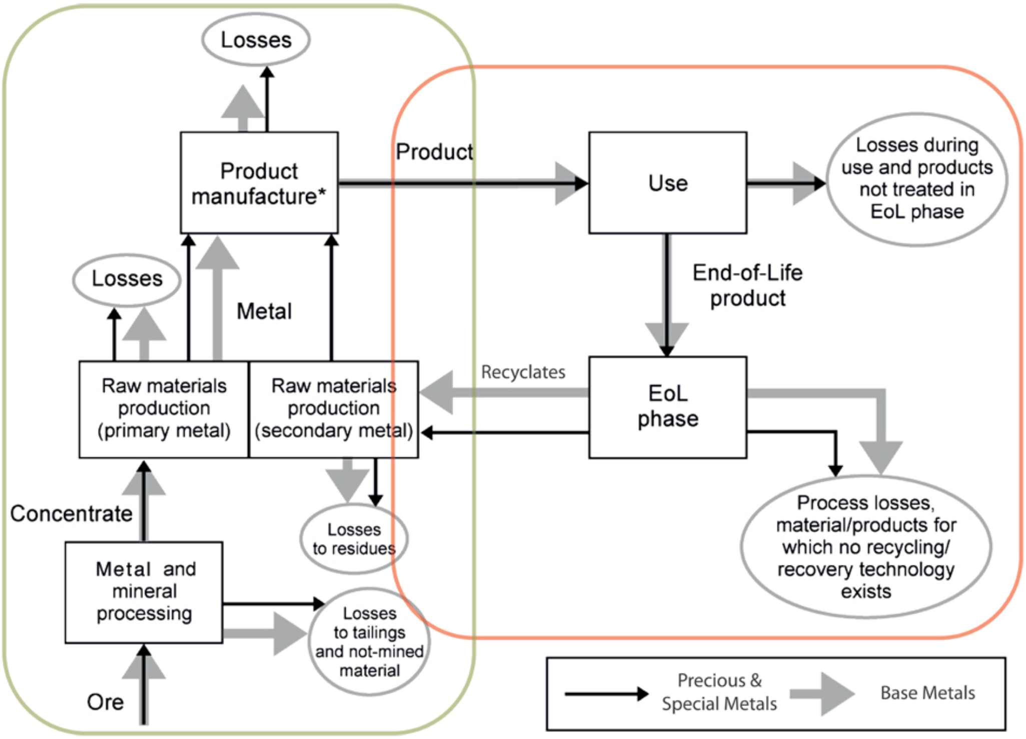

Figure 3: *'Metals/Minerals Flows and Losses in the Product Life Cycle'.* Slightly modified figure, originally presented by Hagelüken & Meskers (2010: 13). Products link precious/special and base metals depicted by combined small and large arrows. This is happening in the manufacturing phase where, for instance, the use of alloys creates complex flows of metals to EoL, (cf. section 5.3). The losses, depicted above, occur throughout the whole product life cycle, but main losses occur when the product approaches the end of its life. Eliminating those losses, by creating pathways of products, components or recyclates to product manufacturers could decrease the use of primary raw materials.

As this study is placed in a European context it is also settled around the present regulation of electronic waste (The WEEE directive 2012/19/EU). Despite being a fairly regulated internal market, putting extended responsibility on the *producers and importers*, systemic holes seem evident (cf. section 1.2). Therefore, the aim is to primarily assist in developing pathways for more sustainable production and consumption systems around electronics, thus specifically ICT products. However, this study does not necessarily seek to step out of the current regulation regime, and so instead wishes to find answers on how both public and private decision makers could arrange and qualify policies or strategies around new initiatives. This also means that no hard distinction has been made between which stakeholders that should or shouldn't engage in each specific process. It is thus seen more important to clarify how initiatives can be qualified by stakeholder involvement from multiple angles. However, in some occasions it's been necessary to state how e.g. further intergovernmental regulation could help the processes to evolve. The possibilities of gathering empirical data and information from stakeholders has also been limiting this study to a more national outlook from where it is being conducted, namely in Denmark. Nevertheless, since the object of study is around electronic devices in the form of ICT products, which evidently have global production and value chains, it is hoped that this study will stand out as an inspirational example to others (outside Europe).

2.2 The Premise of a Transformative Approach

The study originates from simply recognizing the technological possibilities for advancing the development in ICT products (Appendix 2A). The logical reasoning circles around the fact that they are not sustainable today or have not reached a state of sustainability, so: *"how would they become that?"* An important question is thus to ask: *"is it the product itself that must change, or, the system around it?"* This deadlock could spawn many discussions, but one first assumption could be made here, that is, *if the system around the product changes it is likely that the product also will.* Critics would thus make the opposite claim, *if the product changes so will systems*. A deduced midpoint could then be made around a more co-evolutionary position – thus seeing technologies (meaning ICT products) in the centre of socio-technical systems (Geels, 2004: 909f), which cannot be separated from the economic, cultural and social context where they evolve or the natural systems they couple with (Graedel & Allenby, 2010: 67). However, Power & Mont spark a critique of the narrow product-innovative focus taking hold in the past 30-40 years of large investments in technological progress and labour productivity. This has lead to a larger "*share of environmentally sound products on the market. Despite that, the aggregate environmental impacts from consumption of goods are still increasing due to the sheer number and volume of material products on the market (level of affluence) and their growing use by the rising number of consumers*" (Power & Mont, 2010: 10). With this reflection in mind, it was found justified to look at desired change within system transition as a *transformative* prerequisite for the further research (See Appendix 1A for further elaboration).

In the introduction it was thus sought to describe how the post-commercialisation life cycle of ICT seemed problematic and maybe even problem creating by default. Therefore, as a start, the methodological positioning takes it place between so-called *future studies*, often relying on a more multidisciplinary approach and influenced by the need to adapt or to explore the possibility of influencing the future development itself (Höjer et al. 2008: 1959). Future studies, work around establishing and planning in scenarios (ibid.).

In developing the study scope, for this thesis, a largely normative nature emerged. The problem question not only implies a highly valued future goal of circular and sustainable production and consumption systems, but also how to design and apply new initiatives to reach this visionary target. This conforms to a transformative scenario state around system transition and desired change. Therefore, backcasting methodology was found very suitable to apply for this study. The next section provides an overview of the backcasting nature and idea behind.

2.2.1 Backcasting

Backcasting can be seen as a study technique or methodology used in future studies to define visionary targets and rigorously hold the objective of the wish to create a more constructive or 'sustainable' development path. Amory Bloch Lovins originally introduced the conceptual framework in connection with his renowned book *"soft energy paths – towards a durable peace"* from 1977. In the aftermath of the energy crisis of 1973, Lovins played with the concept of constructing future scenarios while working backwards to the present to develop and design a sustainable energy strategy (Damsø, T., 2012: 14). So, Backasting emerged as a response to unreliable forecasting techniques (like the unseen oil crisis) at the time (Höjer et al. 2008: 1959). Therefore, backcasting is about applying the concept of a guiding vision to revile pathway answers to emerging, complex or pervasive problems. This is visualised in figure 4 below:

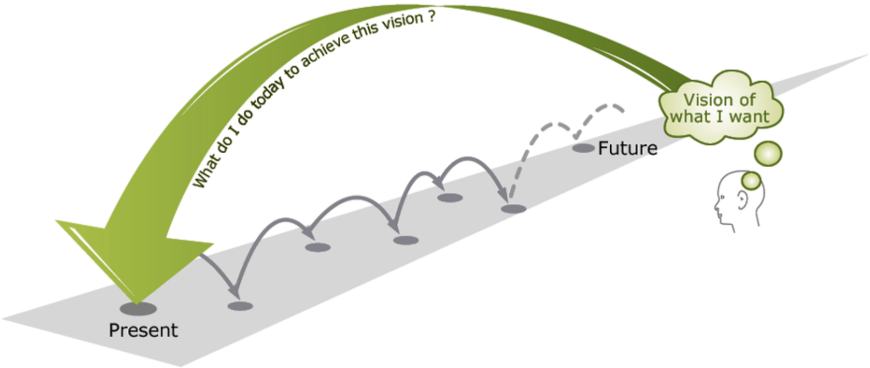

Figure 4: '*The essence of 'backcasting'* - illustration reprinted with courtesy to The Natural Step International, 2013 (CC)

This mind-set was later picked up and further developed by John Bridger Robinson in the 1980's who introduced the term *'backcasting'* (Dreborg, 1996: 814). Most recognisably the NGO *The Natural Step International*, founded by Dr. Karl-Henrik Robért, has pioneered the methodology in their framework for strategic sustainable development (FSSD) since 1989 (The Natural Step, 2013: a) which is their overall system of looking at society in relation to the biosphere (Robèrt, 2000: 247) (Waldron et al. 2008: 11+13) (The Natural Step, 2013: b).

Originally, Robinson developed his methodology as an alternative approach to forecasting, which he, through empirical examples, criticized for being conservatively biased towards the present status quo (Robinson, J.B., 1982: 831f), while he also explained: "*The necessary use of past trends and relationships in forecasting future behavior means that no adequate basis exists for forecasting entirely new variables (e.g., solar heating), which thus tend to be ignored or underestimated*" (Robinson, J.B., 1982: 232). So, as opposed to relying solely on forecasting scenarios, Robèrt later on expressed backcasting as "*the avoidance of technologically walking in blind alleys*" (Robèrt, 2000: 248). Likewise Robinson expresses: "*To the extent that the most likely future is not the most desirable, then what we want are not simply good predictions, but indications of what alternative futures seem available and what their characteristics are*" (Robinson, J.B., 1990: 821). Hence, the meaning is to make a distinctive picture of how a *desirable future* would look, which decision makers can choose to act upon.

However, backcasting is not seen as opposite to forecasting studies, but merely a different strategic approach and so should be viewed as complementarily to the more predictive study techniques. The aim is still to create useful knowledge about future possibilities. Backcasting is also dependent on forecasts by default, since without; it would be hard to see needed change in order to fulfil targets (Højer et al. 2008: 1960).

Backcasting is design-oriented and it is thereby sought to explore the *"implications of alternative development paths"* (Robinson, J.B. 1990: 824). In Holmberg and Robèrts review of backcasting "*from sustainable principles"* they mark it as the need to identify business strategies to meet complex challenges of today, they ask: "*How can ecology and economy be merged together into one strategy that makes sense in the short term as well as in the long term, and from a business perspective as well as for the common good?"* (Holmberg & Robèrt, 2000: 292). This question is somewhat similar to the overall approach of this study.

To finally illuminate the basic features of backcasting, Robinson thoroughly describes and discusses the methodology in his article *"Futures Under Glass"* (Robinson, J.B., 1990). Here, the main steps include:

- **(1) Determine Objectives:** the purpose of the analysis (create an overall vision) and the temporal and spatial scope of the analysis.
- *(*2, 3 & 4) Specify Goals, Constrains and Targets, Describe Present System & Describe Exogenus Variables – *elaborating the present system condition, describe external factors and setting goals for scenarios.*
- **(5) Undertake Scenario Analysis:** Development and qualification of scenarios (in this analytical case by looking for features and new initiatives to take).
- **(6) Undertake Impact Analysis:** consolidate results, assess impacts possibilities and compare with the previously made goals. Finally, the results should be compared with the objectives
(step 1 – the vision & objectives) to discuss and **Determine Implementation Requirements**.

This is a merged description and clarification, based on J.B Robinson (1990: 824f)(also see Appendix 1B)

This study and its final analytical design (cf. section 2.3) is thus mainly inspired by the methodological procedure and considerations defined by J.B. Robinson (1990), which is also referenced throughout the analysis. However, some of the terms and definitions from the more direct and organisational approach originally presented by Robèrt (2000: 247) and thus used by The Natural Step, have been found useful to clarify the scope. An outline of both methodological setups is presented in Appendix 1B.

2.2.2 Critique of Backcasting

Backcasting is sometimes criticized for being normative or political - built on predefined targets (e.g. sustainability) and external factors that are not defined initially (Höjer, M., 2000: 28). It is important to note that backcasting is indeed a normative approach. However, a researcher that takes on, for example, a 'cost-benefit analysis' would also be using normative methods, since he or she would select which external factors to include in their analysis. Any choice of external inputs would always derive from partial uncertainty. Thus, forecasting trends are very much also a "politically" biased situation, since the researcher would be affected by the present paradigmatic state in society - the organisation they represent and so forth. Backcasting often works from the core of extensively outspoken societal targets (such as the need to achieve sustainable development). Therefore, this method might be able to reveal and "*display weaknesses of narrow-minded and short-sighted planning"* (ibid.) During the course of writing this thesis another discussion came up as a critique. Since the visioning creates a future target as a prerequisite, it may naturally produce a positive outcome. Turned around, it can also call into question whether scenario results could ever fail to meet a predefined target, since the measure of success is to establish an idea of how to reach it. This is a valid critical point, but somehow also a misunderstanding of the genome of backcasting. In this authors opinion, the point is not to answer what scenarios will result in (to make a good prediction) but to qualify, visualise and determine what new ideas can provide in terms of reaching a highly valued target - simply what they can or cannot help to transform.

2.3 Analytical Design

In the first analysis chapter (3) the idea of a circular economy and sustainability are discussed as conceptual approaches to economic theory. This was done in order to find key points around these focal areas, used for the rest of the analysis. As in chapter (4), circular system and design approaches has been examined. Finally, derived key points were used to build the main vision and guiding objectives in the end. Chapter (5) reflects the main analysis of the ICT product life cycle after it has been put to market (post-commercialisation). In this analysis, part of the aim is to find sustainable gaps, conflicting with the vision and objectives, hence to establish a final set of sustainability goals. Chapter (6) functions as the scenario analysis, where new systemic initiatives are examined (see problem scope 1.4). In chapter (7) these scenarios will be evaluated for their possible future impact and alignment with the sustainability goals, set out in the previously chapter 5. Ultimately, a final discussion of the scenarios against the vision and objectives is provided, and should lead with the idea of a similar final path towards sustainability. For visual reasons underneath, *the cloud* is where the data is stored, knowledge is condensed and information is shared. See analytical design, in figure 5:

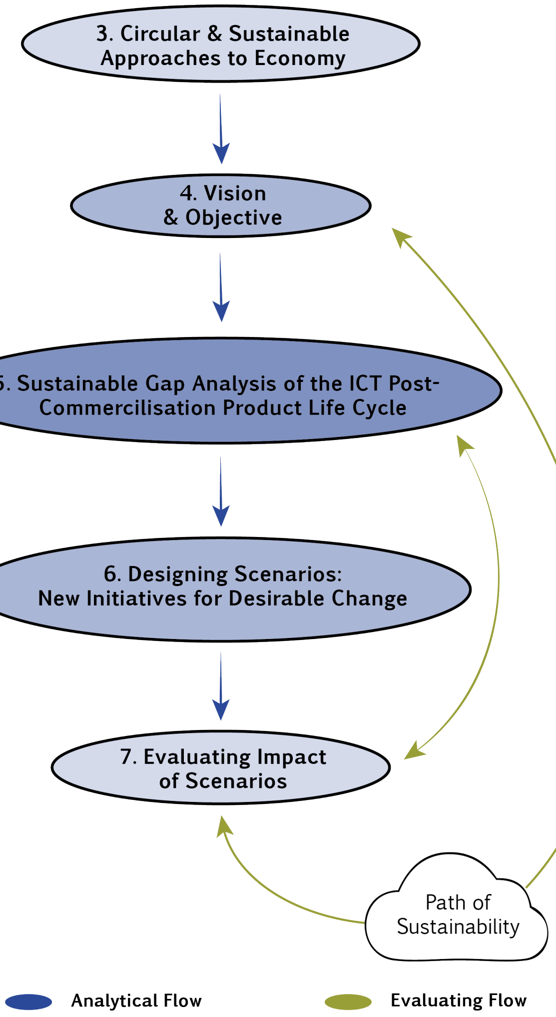

Figure 5: *'Analytical Design'*

2.4 Applied Theory

The use of theoretical inputs for the analysis is mostly confined to chapter 3, where grounding theoretical contributions to a circular economy have been investigated. In addition, it has been attempted to illuminate how the circular and sustainability concepts corresponded with classical and neoclassical economic thinking in the light of environmental economics. Ecological economics were found as a merited critical counterpart to the prevailing economic paradigm, and why contributions from this school of thought have been applied to qualify the analytical discussion. Here main concepts of efficiency, substitution and sustainable resource use are weighted. Conclusions in this chapter are thus assembled and further implemented in the overall vision and objectives for the study defined in chapter 4. More historical and analytical contributions around subjects like design imperatives, technological development, and consumer behaviour from a selection of writers and researchers, have been used throughout the rest of the analysis.

2.5 Empirical Studies

The following sections provide descriptions of the empirical work carried out and used in this study, including: document sampling, semi-structured interviews, online survey and a single company visit at a Danish pre-processing station for electronic waste. The included empirical findings were all targeted to cover specific valuable objectives in the study, namely the linkage 'in-between' the different lifecycle phases of ICT products (See figure 6). Only secondary sources, such as scientific papers, were used to analyse the pre-phase before commercialisation (marked by black circles), while the main efforts of empirical collection and sampling were focused on gathering information about purchase, service and repair of products, plus the collection and processing of e-waste (marked by red circles).

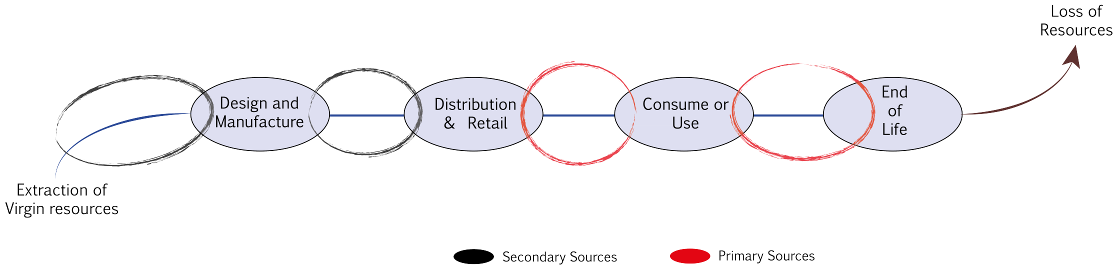

Figure 6: *'Focus of Empirical Studies'*

2.5.1 Document Sampling

The empirical foundation for this study was initiated by studies of relevant official documents from the private, public and scientific spheres. What is important to most researchers is the investigation of similar or pertinent reports of the (recent) past leading to identification of relevant concepts and findings, as well as to demarcate the field of study. To make careful selections of documents and general written contributions, the guiding quality criteria of *authenticity, credibility, representativeness and meaning* (Bryman, 2004: 381) have been used to determine which sources to include and not to include. As an example: so-called corporate social responsibility (CSR) reports from OEMs have found limited use in this study, since they often do not represent the full picture of corporate operations or only what the particular organisation have chosen to publicize. Conversely, the publicized data on specific products and actual corporate programs has been proved relevant for the study objective. It has also been attempted to limit sources coming from political organisations (e.g. NGOs) and so in cases where they have been used, it has been done so only to adopt the more factual data. In some situations inputs coming from both private and public sources have been found useful to cover angles of the study objective, and why it has been attempted to follow with a careful discussion of the data as conclusive inputs. The heterogeneous nature of this study scope, has also led to some considerations about the use of scientific papers and consultancy reports. In this case, the knowledge contexts, novelty and the depth of the particular research (how thorough) have been guiding the selection. Moreover, the normative base of this study has proven very useful, thus the establishment of a grounding vision and objective for the analysis have initiated some key angles to the critical procedure of determining relevance.

2.5.2 Online Survey

An online survey was carried out to collect basic knowledge about people's preferences, experiences and positions towards relevant issues: *purchase, use, services, repair, leasing, disposal and information on mobile phones*. It was made using the free Google Drive application; "Forms"[9] and was generated directly as an online survey from the basis of a spreadsheet. The online survey was primarily directed to around 50-60 people in the author's network. They were encouraged to redistribute it online through their own network (mostly social networks, through e-mail and orally), so the spreading factor could become greater and move away from the source. Additionally, it was sent through the Roskilde University e-mail-system using "markedsplads@ruc.dk", directing it to various subscribers from the Roskilde University server interested in news, jobs, events and more. This mail list is expected to be relatively diverse, including various students and employees on campus. Details about the group of respondents listed here:

- 76% are between the ages of 20-29 and 12 % between 30-39 years of age. Representing a relatively younger crowd of individuals.
- 58% women, 42% male**.** Women were more likely to take the survey, thus extra time was used to find male respondents. However, unfortunately total equality among genders was ultimately not achieved.
- A total of 53% have selected their last finished education as either bachelor or a long-term education (such as a masters), which puts the larger amount of respondents in the category of *higher education*.
- 80% reported having a smartphone as their primary phone (compared to 63% on national level, DST, 2013: a)
- A total of 290 respondents. The goal was a total of approx. 300.
- The survey was open from late April to start of June 2013.

(Aggregated details on respondents, is also found as the result of Q1-4, in Appendix 5A)

A crucial validation point for any quantitative research goes around how representative it is for a given population or a selected group of people, thus setting limits to the generalisation of the results (Bryman, 2004: 77+87+104). This survey was naturally targeting a younger crowd. Meaning that, the outcome on age-differences by surveying this way, wasn't expected to be great from the start since friends of friends are more likely to be the same age as the researcher (the author). Students at the university campus are also likely to be in the same category of 20-39 years of age and thus with a higher educational background. Nevertheless, it has the advantage of somehow representing an insight on the "younger" and maybe more "well informed" consumer and their preferences and experiences, without opposing the idea that is able to be demographically representative for the Danish population as whole. It also means that the homogeneity of the group can be expected to be larger than if it was carried out as a national survey that would be oppositely, more heterogeneous (Bryman, 2004: 99). With a full survey response rate of over 95% and around 250-300

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[9] https://drive.google.com

respondents, there is an uncertainty factor ranging from 2,7 - 2,5 % (TNS Gallup, 2012: 13). The actual total of 290 respondents correspond very well with how many people that would fit in the same selected age group majority (20-39 years old), if the same amount of submitted answers were taken from the normally preferred 1000+ respondents (Bryman, 2004: 97f) equally distributed over different age groups. Security samples were also taken after the first 150 respondents had submitted answers. Here a limited set of answers only switched weight of 1% compared to the final survey. With all this being said, it is important to notice that the results of this consumer survey must be backed by additional research before they are taken to a national scale and most importantly, beyond the borders of Denmark. This also means that wherever possible and in terms of generalising on a bigger national scale, it was sought to discuss results with similar surveys carried out by secondary sources or to remain conservatively biased towards them. The survey is widely used to discover consumer perspectives in the sustainability gaps analysis (chapter 5) and around the analysis of scenario initiatives in chapter 6. Further explanation of the procedure is applied along with the survey results in *Appendix 5A*.

2.5.3 Semi-structured Interviews

Four semi-structured interviews were carried out on relevant stakeholders in the post-commercialisation ICT product life cycle, with the goal of covering structural and strategic possibilities within the regulation and collection systems plus end-flows, handling and processing of e-waste. All interviews were established as semi-structured ‘conversations’ about pre-determined topics with room for discussion, elaboration and clarification of questions. The selected stakeholders and interview persons were as followed:

- DPA-system – Public administrative and non-profit organisation supervising the extended producer responsibility obligations concerning WEEE under the environmental protection act. Established under the Danish Ministry of the Environment.
  Interview person: Johnny Bøwig (Executive Government Official)

- El-retur – Non-Profit ‘Collective Recycling Organisation’ (CRO), Denmark.
  Interview person: Henrik Jacobsen (Project Manager and Controller)

- DCR-Environment – pre-processing company for smaller e-waste fractions, Denmark Interview person: *Simon Rasmussen (Sales Manager)*

- Umicore – Non-Ferrous and Precious Metals Refinery. End processing company, Belgium/Germany
  Interview person: Dr. Christian Hagelüken (*Business Development & Marketing)*

All four interviews were arranged in a more formal character. Therefore, generating ideas, challenges and opportunities, relating to the study scope, expressed by the given interview person on behalf of their organisation. This means, that almost no direct quotations have been used from the interviews, and is why the overall analytical process has been mostly focused on gathering valuable content and points coming up during the conversation. A few of the subjects also stated that they were not to be quoted, which simultaneously fit the study approach to the interviews. The interview with Simon Rasmussen from DCR-environment also included a guided tour on their pre-processing facility. All interviews were targeted to cover life cycle phases in the sustainable gap analysis found in chapter 5. However, the interview with Mr Hagelüken was intended as two-sided and thus also focused on ideas and opportunities for EoL-management – in which points are applied to chapter 6. Not to be confused, Mr Hagelüken have also been involved in several scientific papers, in which some have been used throughout the analysis. A formal example of an interview guide is found in Appendix 5B. The Interviews are all available on the accompanied CD.

3. Circular & Sustainable Approaches to Economy

The idea of 'the circular economy' stands as one of the most relevant debates today. It not only implies an approach to circular systems around natural and financial capital, but also promises a pathway to eliminate externalities crucial to reaching sustainable development. However, the goal of this chapter is to illuminate how these two very outspoken concepts have merged together and which cardinal aspects can be used as building blocks for a vision.

3.1 A Circular Economy

Last year the European Commission stated in a memo called 'Manifesto for a Resource-Efficient Europe' that: "In a world with growing pressures on resources and the environment, the EU has no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy" (EC, 2012 [b]). This pledge from the EC correlates with the resource-efficiency focus, which has been highly prioritized throughout the last decade and follows in the footsteps of the 'Europe 2020' (EC, 2013 [b]) growth strategy and 'The Roadmap to a Resource Efficient Europe' (EC, 2011). Likewise, China has also made a committed statement in their recent 12th 5-year plan, emphasizing that:

> *"In transforming the economic development mode, the importance of building a resource-saving and environment-friendly society should be stressed to save energy, reduce greenhouse gas emissions and actively tackle global climate change. We should develop a circular economy and low carbon technologies. Through striking a balance between economic development and population growth, sustainable development will be enhanced."* (PRC, 2012: 3)

What these statements possess is a clear recognition from the political spectrum that a circular rationale will be and to some extent has been embedded in the political visions. The statements fully correlate this rationale with sustainable development and the fight against major challenges to society. However, a question still arises: *how do we envision a circular economy in the first place, driving business and society to evolve in a sustainable manner?*

Walter Stahel published an important subversion to common economic thought in his paper *'The Product-Life-Factor'* (1981). Here Stahel was actually envisioning a way to create a stable and viable sustainable economy with low unemployment and vital resource-efficiency. He attempted to show that product-life should be extended in so-called *replenishing loops* (a loop economy) where first stage was 'reuse', next 'repair', thirdly 'reconditioning'[10] and lastly 'recycling' scrap as the main source of new product inputs (Stahel, 1981: 1ff). In this way Stahel was envisioning that it could be possible to halt the resource, water and energy consumption. He made a huge effort to explain that product-life should be extended, by transforming to a labour intensive market,

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[10] This is the term Stahel used, but is very often called 'refurbishment' today.

securing jobs, instead of having a capital-intensive market focusing on productivity via economy of scale and 'quick-replaced' 'short-life' products driving economic growth – to where he says: *"It has also meant that an ever-increasing part of our income has been devoted to the replacement of products, maintaining, not adding to, wealth"* (ibid: 2). Stahel was very aware that technological progress should be secured along and that critics would see it as being an obstacle to his loop economy with longer products-lives. Moreover, that interest in keeping cost's down in the private sector and simply not being able to sell as much, would kill this idea, because of the growth apparatus in society. His response to this, not necessarily fulfilling, was to embed the idea of standardization of components and leasing (ibid: 6 +15). Later in the 1980's Stahel and chemist Michael Braungart met several times around their mutual work on the loop (circular) economy. At some point, not exactly defined, it sparked the idea of cradle-to-cradle[11] (circular), in opposition to a cradle-to-grave (linear) economy (Product-Life Institute, 2013).

Therefore, the concept of a cyclical economy can mainly be viewed as opposed to a linear economy as an alternative approach. From this point the concept is very easy to understand; if it is possible to find ways to cycle all the resources used, to make goods and services, theoretically then it should eliminate waste and pollution from any human activity. More precisely, can we extend the value in the actually resources throughout the whole life-cycle, they can by recycled back as inputs for new products (EMF, 2013: 8+10) - a reasonable argument against a current world, where waste and pollution is dominantly seen as a precondition of most economic activity. So this concept has been extensively outspoken in recent years (hence the before mentioned statements from the EU and China). One of the main advocates, The Ellen McArthur Foundation (EMF), was established in 2010 to promote a transition path towards a circular economy. The foundation was founded by large industry partners[12] and cooperates with the renowned consulting firm Mckinsey & Co. to develop the knowledge base.

Somehow it seems this circular idea also challenges conventional economic concepts of what e.g. scarcity, substitution and efficiency implies. For instance, going from having a focus on using as few resources as possible, efficiently in a product, to make efficient circular resource flows that enables e.g. metals to 'substitute themselves' and thereby combat scarcity in a new product life. Meaning that, it is not so much about how little you use of a specific metal, but how well you can design a system that puts it back into new products. However, as easy as it sounds, as difficult it could be to change present institutionalized patterns. Predominantly we could also just see it as a matter of positions and possible conflict of interest. But as a logical reasoning, we could also state that 'any system that produces errors must be subject to reassessment'.

In 1966 American economist and philosopher Kenneth E. Boulding wrote an essay "*The Economics of the Coming Spaceship Earth"* (to which page references here refer to) on the subject of economic thought and

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[11] Later to become famously known as the design-concept cradle-to-cradle (C2C), used in the book of the same name by the same Michael Braungart and William McDounaugh (2002).

[12] B&Q, BT and Cisco, National Grid and Renualt – see also: http://www.ellenmacarthurfoundation.org/about/partners

evolution - in relation to contributions by Stevenson (1965) and Ward (1966). To this day it stand as fresh and relevant as it was when it was first published. In the text Boulding investigates man's relationship with open and closed systems of matter, energy and knowledge (pg. 3). Boulding begins by saying *"We are now in the middle of a long process of transition in the nature of the image which man has of himself and his environment"* (pg. 1). The transition, which he speaks of, is the road towards an economic paradigm in which man must recognise Earth and its natural resources as being a closed and thereby limited (a finite system). Here, economic principles of the future must apply to this world (pg. 7). The discussion he carries out, starts by recognizing and understanding that man, for the majority of his time on earth, has been living in what seemed to be an unlimited world. There was always a new *frontier*, new resources to exploit or new places to go to - he explains *"The image of the frontier is probably one of the oldest images of mankind, and it is not surprising that we find it hard to get rid of"* (pg. 1). This is probably why more techno-centric approaching solutions to this finite planet notion, continue on by claiming space as the next frontier for human resource exploitation[13]. Ironically enough, Boulding explains his positive vision for the future back in 1966 as *the spaceship economy*, but where the simple survival means of efficiently recycling matter on a modern spaceship (pg. 3f) was the point behind the picture:

"I am tempted to call the open economy the "cowboy economy," the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behavior, which is characteristic of open societies. The closed economy of the future might similarly be called the "spaceman" economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy."
(pg. 7f).

Boulding here describes the present economic system in a humoristic way as a *'cowboy economy'* where new land (the frontier) always seems available. In his discussion on the open and closed systems, Boulding explains that energy based on matter must come from renewable resources by the direct inflow of sunlight, since chemical ones (fossil fuels, nuclear and even possible fusion energy) will eventually run out and leave man with his current energy input from the sun (pg. 6). Most importantly, Boulding views the knowledge base as an open system, which society reproduces but should cherish and protect. If it is lost it cannot be regenerated. Hence he sees this knowledge as a precondition for utilizing matter and energy (in an efficient manner), which is why it must be protected (pg. 7).

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[13] New missions for so-called 'asteroid mining', attempted by e.g. NASA, show that there is significant economic and futuristic interest in human outreach to celestial objects in space (NASA, 2013).

For decades, ecological economist Herman E. Daly has pioneered alternative economic thinking since his work *the steady-state economy* (1973). On the quest for man's general missing recognition of the earth's physical boundaries - the biosphere as a finite system - he explains: *"As the world becomes full of us and our stuff, it becomes empty of what was here before. To deal with this new pattern of scarcity, scientists need to develop a "full world" economics to replace our traditional "empty world" economics"* (Daly, 2005: 2). Daly's description of the world is also about recognized earth as the finite system that it really is. Even though science fiction sometimes challenges science fact, a sub layer to the point is actually embedded in his idea of a "full world". Taking matter from the earth's ecosystems and transforming it in to something else will change, and has changed, the face of the earth. Therefore, what he says is that we need to preserve our natural surroundings, since they are the ones that ultimately sustain civilisation, and stop creating a planet full of waste – Or stated in a more direct way; physical stuff will pile up over time if something is not done. Therefore, the equation in Boulding's argumentation and Daly's full world picture, presently speaking, is that we as humans cannot simply just become 'space-cowboys' as a solution to resource problems (scarcity), but must preserving knowledge to recycle matter instead, because the opposite would leave us with a planet full of growing junk piles and flooded ecosystem sinks. It thus seems this is where the ethics of conventional economic thought is put to the test.

In conventional cost-benefit thinking it is believed that these 'externalities' can be initialized and prevented by simply adding value to them (Pearce, et al., 2006: 31). Environmental pollution is seen as an external cost to the effect of extraction for production and consumption, and so ecosystems will act as sinks. Recognizing these sinks as having limits, that if exceeded can have negative impacts on human wellbeing, leaves the economist with the task of applying external cost to the equation (Turner et al. 1994: 4). While there are surely some contradictions between environmental economics and ecological economics, in which some of the approaches differ, the goal in both approaches is clearly to address the environmental and social externalities of (un) economic behaviour. It is more a question of the foundation (on how it is done), valuing altruism, valuing posterity, valuing limits and what fits the particular purpose.

3.2 To Adopt a Circular Economy

The more direct ability to actually adopt the circular rationale in new businesses models or regulation, to address the quest of reaching sustainability development in real life, can be summed up by various contributions, ideas and concepts – many which are backed by various empirical samples.

Lisa Gansky talks about the mesh of things, or mesh businesses, where: "the core offering is something that can be shared, within a community, market, or value chain. Including products, services, and raw materials […] the focus is on shareable physical goods including the materials used, which makes local delivery of products and services – and their recovery – valuable and relevant" (Gansky, 2010: 16). Peter Senge talks about the revolutionizing impact of non-governmental organisations (NGO's) from only 700 in 1992 to that of the millions today, and that their huge impact in getting full transparency from corporations, globally and locally, forces these odd partners to create a symbiosis of efforts through the whole value chain - and so sustainability must be embedded in a both global and local nature (Senge, 2010: 367ff). Hawken et al. (2001) talk of the continual stream of services and the transition from a goods and trade economy to a service and reprocessing economy, focusing on deep relations with costumers and their ever changing value set, automatically rewarding resource-efficiency and closed-loop systems. E.g. instead of selling kWh or lamps, you sell the comfort of a certain indoor temperature or lightning (Hawken et al., 2001: 29f + 159ff). Charles Eisenstein talks of business in a gift economy, where after the total basic costs (materials, labour) have been covered, the costumer pays a gift according to his or her level of gratitude for the service they received, somewhat of a tip or bonus, the service-provider receives for doing a satisfying job satisfying. The better the services provided, the better the reward from the customer (Eisenstein, 2011: 409f).

To sum up - the idea of a circular economy and the phases a product goes through in its life can be assembled into a *simplified* circular and linear model, as seen in figure 7:

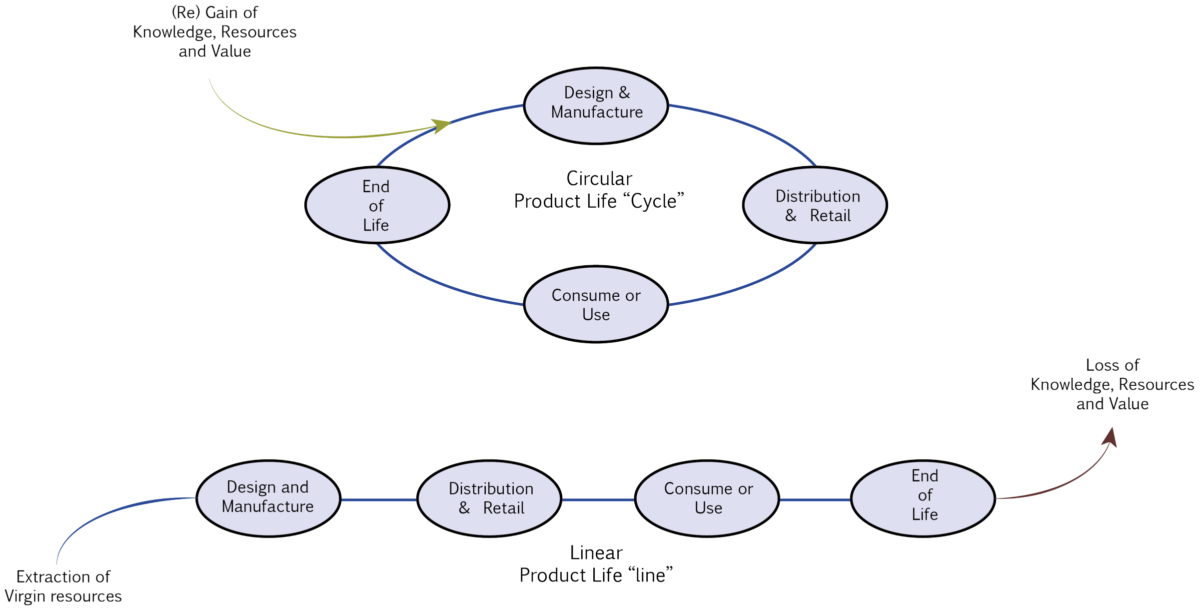

Figure 7: '*Circular versus Linear Product Life'*. The figure presents the same four main phases "design & manufacture", "distribution & retail", "consume or use" and finally its "end-of-life". The top pictures a circular path of a product life and the bottom the "normal" linear one. In the linear model the extraction of virgin resources enters first and eventually become waste in the end. In the circular model resources are directly linked from the EoL phase, in the circle, with the design and manufacturing phase, creating no waste flow. Some resources have to enter the circular flow from outside in the first place, but if the circle flow is not broken afterwards it can theoretically go on "infinitely". Non-renewable (finite) energy as well as hazardous substances, which are not viewed in the figure, can easily enter both models but could as easily, by choice, be substituted by renewable energy and non-toxic substances, thereby, here seen as an extra or external factor. What is unchangeable, and therefore differs between the two models, is the *"gain"* or *"loss"* factors of *knowledge, resources and value*. Thus in relation to Bouldings think piece, knowledge is important to preserve since it enables e.g. an OEM to optimize its product design for better recyclability and in reclaiming more resources and value. In this way, establishing a direct link between these three pillars, from the EoL phase and on to the design and manufacturing phase, constitutes the fundamental target.

The reality today is a mixture of both models. Some reclamation of resources is fully established through e.g. the European WEEE regulation, which enables some linkage between OEM's and the recycling industry through upholding the EPR principle. However, the present regulation just doesn't ensure that all resources actually go back into new products and new virgin resources getting exploited. Additionally, it can be said that the circular rationale has many contributions and can be seen as a bilateral paradigm developed over the years as a response to the dominating ‘throw-away’ thinking. Here, relevant discussions on resource substitution, scarcity and resource efficiency will be further analysed to find the correlation to sustainability in economic theory.

3.2.1 Sustainability & Economy

In economic theory on sustainable development (SD) a transfer of an aggregated capital stock between generations, no less than the size of the present, is the main focus. This is also called *the constant capital rule* (Turner, et al., 1994: 56) (Graedel & Allenby, 2010: 16). This economic rule is related to the well-cited SD definition set out by the Brundtland Commission in 1987[14]. Therefore, the variation of the constant capital rule lies in the detail of transferring capital between the present and the future generations. This definition offers, in many cases, little guidance to the ones that work with *principles of sustainability* – engineers, designers, scientists, organisations, companies and so forth. What is required is the figuring out of what specific actions and choices need to be made to move in that direction (Graedel & Allenby, 2010: 15).

One keyword when discussing and examining sustainability, in economic terms, is *substitutability*. To substitute a resource is to replace it with another – normally to achieve the same function in the production system. In environmental economics the discussion reflects the level of substitutability, for instance to which degree financial capital can replace natural capital. Capital, embeds the understanding that to possess capital it must be available to transform in to a good or a service required by man. Therefore, ultimately we can transform *all* natural capital in the world in to financial capital, but this would logically terminate the foundation for life on the planet; however, if we want to substitute one with another today, we may save some financial capital to re-invest or leave those of tomorrow with the same amount of capital, in another form, as taken from the natural world in the first place. In this way we can offset the materials we took from nature, by replacing them with roads, machinery or other man-made physical capital (Turner, et al., 1994: 54ff). If we make radical technological and innovative shifts, we can maybe go from one material and substitute it with another, or use the first more efficient and thereby expand its availability over time. In this respect, if we imagine we were learning how to create very efficient transistors in the future without using silicon (Si), we can say we have substituted a key material in e.g. microprocessor manufacturing.

However, in this sense that *we believe* we can offset any form of capital, we make a strong assumption based on so-called *perfect substitutability*. This assumption is also referred to as the *weak sustainability* (WS) *constant capital rule* (Turner, et al. 1994: 56) (Halsnæs, et al. 2007: 35). And why is it weak? This thinking is very techno-centric, meaning that any man-made form of capital is as valuable as the ones provided by nature (theoretically speaking). In this concept we believe that technological development eventually will help to

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[14] "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN,1987)

replace the “lost” capital or outdate the usefulness of it. This would also mean that one day we would be able to substitute elements like gold, tantalum or cobalt from electronics manufacturing with something else. And so it also seems some alchemist thinking is embedded in this form of notion.

The opposite interpretation of SD can obviously be referred to as *strong sustainability* (SS). Here, 100% substitutability is viewed as impossible and thus imperfect. Most natural resources cannot be replaced by man-made capital and some ecosystem services are seen as vital for life support and thereby human survival – hence, these are irreplaceable. For example, these could be intact hydrological systems, forest eco-systems, a stabile climate and so forth. The SS approach is true to fundamental natural science facts such as: matter on the planet is finite, biodiversity upholds life, and clean water is necessary to be able to live. Thus SS operates with a *critical natural capital protection rule*, which is outspoken as the *precautionary principle* (Turner, et al., 1994: 57). Therefore, the two opposing forces of SD in economic theory go from the distinction between a techno-centric to an eco-centric paradigm – hence, varying in strength or belief (Turner, et al., 1994: 221).

Today, it is probably hard to find individuals that oppose the fact that some ecosystem services are ultimately vital for life on the planet and thereby needs some sort of universal protection. These are in economic thinking also called public goods. Regardless, *“anyone who accepts the basic premise that global ecosystems create life-sustaining ecosystem services must believe that public goods are critically important”* (Daly & Farley, 2011: 180). However, the degree of environmental protectionism is not essentially agreed upon as what is viewed as a public good. What is more evident, is that what we essentially know is necessary for natural flourishing, is not actually what we are generally building our production and consumption systems on. The linear product cycle, where natural capital (matter) is turned in to commodities and eventually becomes “waste”, shows a paradox in relation to the science we have about the natural world. If the market structure of our economic system only provides incentives for solely producing and allocating market goods it will eventually undermine the production of invaluable public goods (Daly & Farley, 2011: 180f). The protection of public goods for posterity can therefore only be a matter of political choice and real policy.

A timeframe or temporal targets are another discussion when examining the sustainability approach. How we want to allocate resources for future generations to use (consume) and prosper from (and finally for their well-being) is essential to the general sustainability discussion. This also includes the simple protection of existential valuable resources like the biodiversity heritage and nature sites (Halsnæs et al., 2007: 33). Consequently, the *level of depletion over time* has enormous impact when assessing the natural resource state. Long-term predictions though, have several implications. Nobody can tell what the future is going to look like and thus must turn to either good predictions or pure fiction. There is, literally speaking, a google of possible outcomes for the future depending on the e.g. the development in technology, societal structures, human welfare, the natural state and so forth (Turner, et al., 1994: 221). Therefore, we can in reality only assume that future generations would like to use some of the same materials, as we are using today, for their own prosperity – and be visionary.

Electronics of today are almost only made from non-renewable resources, meaning exhaustible minerals and fossil fuel based petrochemicals for plastics, so the issue of *scarcity* and allocation over time is also an issue of depletion rate and impoverishment of the future generations. Since extracted mineral resources are essential market goods the discussion becomes: how will the market prevent the depletion of such? If demand increases, prices will go up, to ensure the efficient allocation of the scarce resource, and maybe extending its availability over time. As the resource becomes scarce, the economic rationale (in line with Ricardo) says that:

"Extraction companies put more effort into exploring for and discovering new deposits and technological advances will allow such deposits to be utilized (e.g. more efficient mining/drilling methods and new 'processing' methods to raise the quality of the resources). In addition, the market will react to ricing price/cost signals by encouraging substitution (new materials and/or new ways of using materials), more efficient resource usage and increased scrap recycling activities" (Turner, et al., 1994: 222).

Here we arrive back at substitution and ultimately the use of *scrap resources* (waste), meaning that technology development eventually should lead us to recycle our landfilled wastes – what has today also been termed *urban mining*[15]. This is the basic claim from a more neo-classical economic perspective, but what will that leave us with? There is no evidence that adequate substitutes will be produced for every vital resource, and moreover, what will happen when the resource becomes increasingly scarce (Daly & Farley, 2011: 183). The obvious answer to this, would maybe be an increasing incentive to extract resources of lower and lower quality and availability, before it becomes economically attractive to recycle wastes. Not only will the ecosystems often be impacted badly due to increased extraction of minerals (cf. Appendix 3D), but it will probably also leave the planet with a lot of old mines (spatial change of the common natural heritage). This negative picture must favour increased protection of the natural state (our common public goods). From this perspective, the only solution to scarcity and eventually depletion of vital mineral resources are to *some extent*[16] to treat them as public goods with policy and regulation to follow – thus to favour the precautionary principle.

To combat this paradox of both protecting and using non-renewable minerals (maybe vital for production), we normally assess costs and benefits in the future by using *intertemporal discounting* of the resource base – to eradicate opportunity costs. The idea is by creating a discounted net-present value (NPV) of the future assets, this will give us the ability to choose from a present perspective of the least harmful materials and so make our favourable investments (Daly & Farley, 2011: 315f) (Halsnæs et al., 2007: 41). While this might be a useful tool in an individual strategic setting, it would to some extent leave us with the weak-sustainability criterion, causing us to devaluate the cost and benefits to posterity from resources extracted today.

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[15] e.g. see www.urbanmining.org

[16] "*An equal distribution of finite non-renewable resources among a virtually infinite number of future generations would imply no resource use by any single generation. But there is no point in leaving resources in the ground forever, never to do anyone any good, so an upper limit to exhaustible resources for any one generation might be determined by the waste absorption capacity of the environment"* (Daly & Farley, 2011: 314).

Therefore, the belief in substitutability (in the future), which lies as a foundation for discounting future costs, must be followed by allocation of matching R&D investments today and policy to bypass future use of target materials. And here we must recognize that technology cannot really substitute a material alone it can only compliment its utility, which in most cases would still uphold its use and sometimes maybe increase it (Daly & Farley, 2011: 202+320). In other words, this means that we must see technological development as an incremental innovation tool (add-on) within a finite system, which may let us use less of a material (be more resource-efficiency) but never to eliminate all resource use.

When mineral extraction occurs today, providing a market good, it has ultimately a cost to our public goods (irreversible destructive impacts on the natural ecosystems and society from where it is taken) and these costs are often far from counted in the equation. And so, if we develop a NPV of our present investment opportunity + cost of lost public goods, we will only see the profitability from our own perspective and never encounter assumed preferences of the future generations (Daly & Farley, 2011: 317f). Thus, in one scenario it might be economically favourable for us to cut down a forest anyway and dig up the minerals since they are worth a lot now and we "forget" to account all the services we receive from protecting it. Additionally, cost and benefits cannot be accounted for the far future using discounting, and so it is impossible to predict if posterity might favour the forest standing tall into eternity. This means, the discounting option seems unusable in approaching a long-term sustainability vision as the foundation of an altruistic business and regulation initiative. A sustainability vision must encounter the reality for future generations with no implications of virtual costs values today. Therefore, some degree of intertemporal distribution must be the foundation for our sustainability criterion.

If sustainable scale, just and equal distribution between generations is our goal, principles of efficient allocation of resources must be our means. Even though, using resources implies an impact on non-market goods and maybe externalities to society. The allocation between non-market goods and markets goods can also be referred to as *macro-allocation*. Where efficient allocation between markets goods can be seen isolated as micro-allocation, macro-allocation is a government task, since societies theoretically are the only providers of non-markets goods – hence also the logical protectors of public goods. In this regard, fiscal policies are essential to secure efficient allocation and sustainable scale as opposed to monetary policy that only drives further production and consumption of market goods from natural capital (Daly & Farley, 2011: 342-345).

This begs the question of how a private corporation, e.g. producing ICT products, embed scale and allocation in its own governance structure, for suppliers and general manufacturing? Since they are ultimately the users of natural capital, transforming it into market goods, they also control a reasonable amount of the demand. The scale of supply of natural capital is ultimately provided by various government regulations around the world – offering extraction rights to private contractors, transfer of property rights and so forth. This leaves us with two logical corporate strategies to combat volatile metal scarcity: 1) *Adaptation to increasing prices and price instability (volatility) by using resources more efficient and maybe leave the innovation incentive to others (the market)*. 2) *Seek abundance, using increased re-cycling and re-distribution for own supply chains by increasing* *control and cooperative policies towards full recovery of finite natural resources in the EoL phase of own products*. For an industry in the likes of ICT product manufacture, that heavily relies on exhaustible raw materials for the manufacturing throughput, the first option seems to reflect a short-term strategy, where the second seems to reflect the opposite – *and a maybe more sustainable strategy*.

In a global perspective some general recognition of metals and minerals scarcity seems to be advancing today. Pricewaterhouse-Coopers made "*a survey of senior executives of leading global companies on the impact of minerals & metals scarcity on business"* in December 2011 with 69 respondents (Schoolderman & Mathlener, 2011: 1). Evident in this survey result was a clear recognition that metal scarcity is set to become a major problem and is already largely affecting business among various industries. Among those, 14 high-tech companies (no names attached) responded to the questionnaire: 78% of the high-tech companies perceive minerals and metals scarcity as a pressing issue for the company (ibid. p. 9). 67% said they already were affected by mineral and metal scarcity and 78% believe they would be increasingly affected in the coming five years[17]. Consistent with what could maybe be presumable, 67% indicated that this would mainly hit their first tier suppliers (ibid. p. 14). Then, when it came to reasons for this scarcity problem, a *growing demand*, *geopolitics*, *extraction shortage* and *low substitution rates* were believed to be the root of the scarcity problem (ibid. pp. 16-17). Most importantly, was the perception of applicable actions to take; for the high-tech industry 89% indicated '*more substitution'* to be the answer, while overall the respondents indicated '*more resource efficiency'* (ibid. p. 20). Therefore it seems that the first strategy is prevailing today at least among industry leaders.

3.2.2 What Does History Tell Us?

It is almost unquestionable that metal ore reserve base is becoming heavily scarce in these years (see figure 8). Looking at the historical numbers it is fairly certain that there has been a dramatic change in the last decade or so. Metal prices fell in 2008-2009, but quickly recovered in the economic downturn. The increased demand from rapid growing economies like China has contributed extensively to the rise in metal prices (Schmidt, 2012: 1). While figure 8 shows prices on base metals, the complex nature of metals in the earths crust also lead to price dynamics around precious and special metals[18] due to their interdependent relationship as geologically coupled, and thus also coupled as part of either a primary production, as by-products or as increased use as substitutes for each other (Hagelüken & Mesker, 2010: 176f) (Schmidt, 2012: 3). This means, metals have low price elasticity.

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[17] Obviously from when the survey was conducted and so towards 2016-2017.

[18] Also see section 5.3 for description of base, precious and special metals.

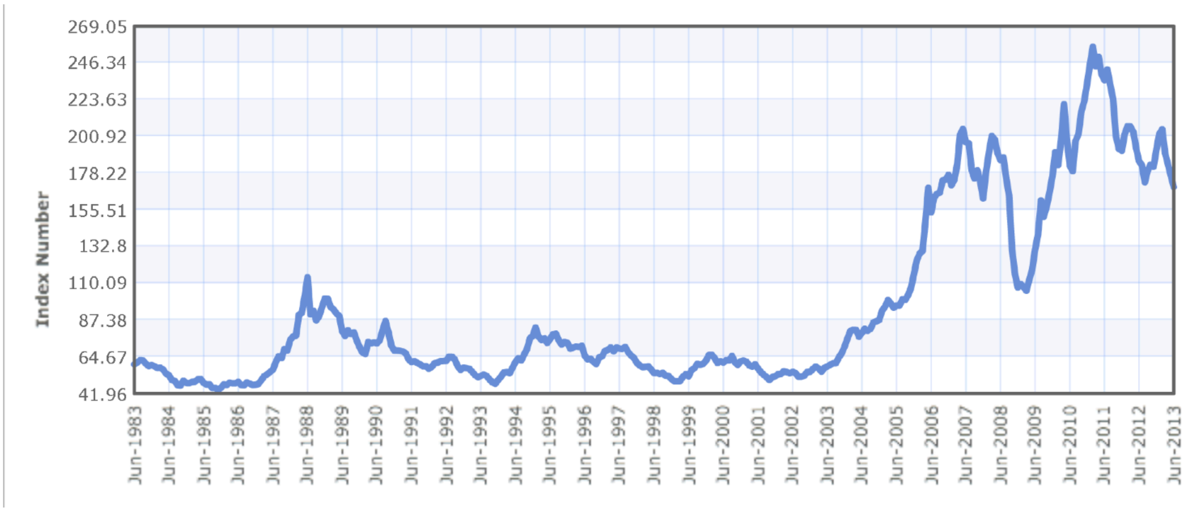

Figure 8: 'Commodity Metal Prices in the Last 30 Years – June 1983-2013'. (Index 2005 = 100) Including: Copper, Aluminium, Iron, Tin, Nickel, Zinc, Lead, and Uranium Price Indices (IndexMundi, 2013). Data Source: IMF. From June 2003-2013 aggregated prices have increased with over 110 index points.

In figure 8 we see that prices were fairly steady from the 1980's to the early 2000's. The reality is though, that metal prices have been relatively declining in the last century (from 1900-2000, viewed in 1997 prices), with the exception of gold due to the fixed gold standard, which was used until 1968 where after the US decided to no longer use it. Since then, the market has set the price of gold. It was used as a hedge against inflation in 1980's and the price has then dropped both in constant and real prices until the early 2000's. The most phenomenal price decline is seen through Aluminium, which absolutely declined in the whole period 1900-2000 (USGS, 2000).

The case of Al tells a longer story of general technological progress in 20th century, increasing supply with ever increasing demand. The dramatic price drop for Aluminium has originally to do with the invention of the Bayer Process and the Hall-Héroult process (1886-1888) (ibid). In the same period (<1900) global population has grown from 1.6 billion to over 7 billion today (UNDESA, 2013), and so unavoidably increased demand on non-renewable resources and everything else (cf. section 1.1). Together with a globalized demand (globalized markets), financial and opening markets and technological innovation, lower and lower grade of metal ore has been effectively exploited around the world (USGS, 2000). Therefore, this has seemingly led to a decrease in *marginal extraction costs* (MEX) for a long time, which now seems to be caught and overtaken by scarcity.

What does this tell us? It tells a story of an immense efficiency focus, which may now be backfiring. The opportunity costs for resource extraction in the past has created few incitements to keep natural capital intact (under ground) and since demand has grown at the same time it has resulted in price declines. And so, according to Farley and Daly, we can talk about a *scarcity rent* creating extra *user costs* for the present and the future generation. This is a result of too low *marginal extraction costs* and *marginal external costs* (MEC) created by resource efficiency and low social and environmental royalties paid to society (Daly & Farley, 2011: 194-197 + 202-204). This critique has been very severe for many years and is explicitly followed in the work '*Natural Capitalism'* (2001) by Hawken et al. As they state, we should remember that markets function according to their ultimate purpose, by *allocating resources effectively in the short-term*. A hard fact, as they state, is that markets do not see living things as anything but dead things, the natural boundaries are an obstacle, billions of years of natural evolution and succession is cheap and the future has no real value (Hawken et al. 2001: 293f). This is no absolute critique of capitalism; this is a status of how our markets simply function with no real ethical choices directly attached to them.

Recognizing scarcity is often also referred back to classical economist Thomas R. Malthus' (1766-1834) famous argument that *population growth* [Y] would never be able to surpass the *surplus in subsistence* provided by nature [X] (Malthus, 1788: 10). The principle that Malthus argues is that these must stay equal. If dynamics appears, creating insufficient surplus, natural laws would force regression in population. The question Malthus pursued was related to food provision while scarce metal resources today do not necessarily imply the same direct causality between supply and human population. But metal scarcity could imply impoverishment of the present and future generations and thereby also corporations, which profit from using these natural resources in manufacturing. In light of the Malthusian analogy, it seems society until now has found shelter in resource efficiency to relieve the negative means of this equation.

However, if we go back to the analogy of Ricardo, mentioned earlier, the scarcity situation could also help us through the increase in real prices and thus nourish new attempts to be more resource efficient and start recycling scrap of obsolete products. However, here it is just important to mention two things. The first option of becoming more efficient, meets the also well-established argument by W.S. Jevons, who proclaimed "the coal question" (Alcott, 2005). So-called *rebound effects* have shown to be very evident and extensively discussed in various studies (ibid.:10). The second option of recycling scrap (urban mining), meets the challenges of entropy, where it can be literally thermodynamically impossible to recycle complex metal combinations of e.g. e-waste, ones it is merged together in a end-product (Hagelüken & Mesker, 2010: 185) (Schmidt, 2012: 4) (Daly & Farley, 2011: 68f) (UNEP, 2013: 278). This means that the most obvious solution to the substitution, scarcity and efficiency problems in the light of economic sustainability, must be to take the best of both worlds and become more "product-efficient". Not to be confused with productivity, but to see these challenges as an opportunity to systematise the use of products and their materials again and again. This approach goes well together with the circular idea of replenishing loops that Stahel originally proposed.

3.3 Interim Conclusion

Knowledge, or information, of products must be preserved throughout the whole lifecycle so it becomes possible for stakeholders like manufactures, retailers and recyclers to systematize the regain of vital resources and hold value intact. As obvious as it sounds, recycling and recovery is really about getting as many resources back in new products and not only treated. Technological development is important to resource efficiency and future substitution possibilities, but *must* also be seen as an added factor to conserve resources and to keep their value transferring in circles. Here, replenishing loops of reuse, repair, refurbishment and recycling is crucial to combat the effects of scarcity rent we see emerging and create an efficient use-life around the product instead. A circular economy therefore first and foremost embeds how to sustain resources and keep them intact.

4. Vision and Objective

In correlation with the methodological procedure, the analytical task is to establish a guiding vision (and objectives), define its geographical scope and a time horizon (Robinson, J.B., 1990: 824f)(The Natural Step, 2013: c). A 'vision' is defined in classical terms by the ability to *think about* or *plan* for the future with imagination and wisdom (Oxford Dict.). This means that a vision stems from a state of mind that would be difficult to legitimize through a narrow reasoning (cf. section 3.2). Therefore, a vision is the foundation for "*the bigger picture*" and the *"whole-system"* context (The Natural Step, 2013: c). In combination, the circular and sustainable approach to economy that was elaborated in the previous chapter will here be used as a mediator for finally conducting a set of objectives. As a start, it is found useful to balance any vision against the well-established circular approaches to production and consumption systems and product design principles. Secondly, to elaborate on the actual technological development today, that could be useful in recycling and recovery of metals from ICT products and thus maybe incorporated into eco-innovative system designs of the future.

4.1 Circular Production Systems & Design Approaches

Key concepts of environmental protection and models to initialize impacts of production and consumption systems have evolved over the years from pollution control through cleaner production, lifecycle thinking, closed-loop production (CLP) and industrial ecology (OECD, 2009: 9). Relative to the theoretical apparatus of this analysis, some features corresponding to the precautionary principles of strong sustainable thinking can be found in the closed-loop and industrial ecology concepts. Here, figure 9 illustrates a closed-loop production system:

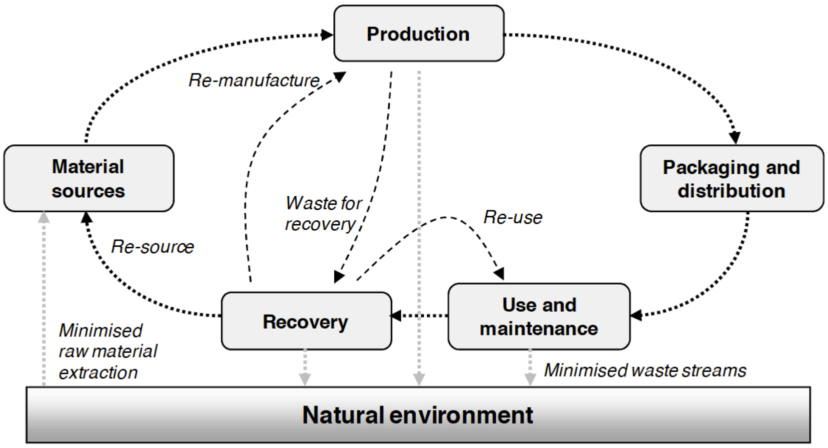

Figure 9: 'Closed Loop Production'. Reprinted, courtesy of (OECD 2009: 10). A CLP system utilizes the opportunity to cycle and transfer raw materials through different channels as recapture value and opposite confine primary resources use and eradicate or minimise waste and thus emissions to the natural environment (ibid.). Tools of reuse, remanufacture or recycling and recovery of materials for product manufacture are used to enable resource flows in circles (in line with the vision of W.R. Stahel described in the previously chapter). In this regard, an OEM would enable a deeper R&D focus of how to recover most value as a part of increasing resource efficiency and neutralize any negative emissions to the natural environment.

Taken a step further, industrial ecology (IE) consciously incorporates the ecosystem link as an inspirational association to core functions of biological ecology/systems (Graedel, & Allenby, 2011: 41). And here Graedel and Allenby define IE as: *""the study of technological organisms, their use of resources their potential environmental impacts, and the ways in which their interactions with the natural world could be restricted to enable global sustainability"* (ibid.). IE is much like the study of bio-mimicry[19] interested in emulating nature's core systemic cycles of energy and resources. The industrial "organism" or metabolism (in line with an OEM) seizes through the use of energy (e.g. free energy - sunlight) and resources to produce and transform "non-organisms" (products) and exchange waste products with other industrial organisms (symbiosis) and the release of excess energy in the form of heat (high entropy) (ibid: 42+52). The idea of creating food-webs is essential, where the OEM maps their interdependent resource exchange with e.g. smelters, refiners, scrap dealers, disassemblers and disposers to optimize the feed stock for production and to confine waste. The spatial dimension can vary from within a single organisation to a regional, or global scale, thus the complex of transport ways and management increases (ibid: 226-233). In IE the OEMs relationship with recyclers is an extended network (equal to bacteria in nature decomposing dead material), where the recycler can return accessible materials to primary production (manufacturing) and possible of higher quality down the supply chain (as a higher trophic level). Another important actor is the relationship with disassemblers, which can retain resources at higher "trophic" levels (whole components), passing as little as possible on to recyclers. As biological systems, OEMs would have and seek a very limited intake of resources from outside the system. (ibid: 224).

However, Graedel and Allenby also point to some economically positive distinctions between IE and biological ecology. As a correlation between the two worlds OEMs would be quicker at *adapting to change* with redesigns or negotiating with suppliers, whereas a biological system need slow evolutionary transformation periods to adapt to e.g. new diseases. OEMs would also be quicker at responding to increased need or low market supply of resources since there feed-stock is in place, instead of relying distorted/volatile markets from scarce primary production (maybe jeopardizing market shares). Finally, where biological organisms are experts at working in their own environment (responders) industrial organisms strive to define theirs (initiators) (ibid: 225).

Therefore, OEMs moving in the direction of CLP/IE would be able to seek abundance apart from navigating on markets ruled by scarcity, thus creating resilience through interdependent relationships in the form of e.g. disassemblers and recyclers.

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[19] Bio-mimicry is very much also a study of designing through natural shapes and forms. More information can be found at the website of association and consultancy, Bio-mimicry 3.8: http://biomimicry.net (2013)

Finally, we can also turn the focus on to the product itself and principles of eco-innovative[20] designs. In correlation to industrial ecology and general closed loop production systems, cradle-to-cradle (C2C) offers a simple design concept also inspired by natural cycles. The concept goes: *waste is obsolete and does not exist in nature*. And so, McDonough and Braungart formulated this well-known bilateral distinction to base product design on:

Biological Metabolism: "A biological nutrient is a material or product that is designed to return to the biological cycle [….] the idea is to compose these products of materials that can be tossed on the ground or compost heap to safely biodegrade after use literally to be consumed" (McDonough & Braungart, 2002: 105).

Technical Metabolism: "A technical nutrient is a material or product that is designed to go back into the technical cycle, into the industrial metabolism from which it came […] isolating them from biological nutrients allows them to be up-cycled rather than re-cycled – to retain their high-quality in a closed-loop industrial cycle." (ibid.: 109f).

The technical metabolism gives a strong design rational to closing loops. Also, biodegradable, soluble and separable polymers may well be some of the next step in technological innovation of electronics for the future (Appendix 2A). And so, C2C somehow also embraces some of the concepts that are normally collected under the umbrella of *Design-for-X* (DfX). Here, the *X* stands for several parameters like *design-for: disassembly, or, environment & sustainability.* DfX can be referred as a set of design methodologies or objectives that can help designers address life-cycle issues (Sundin, 2010: 38+44).

If the idea of C2C seems a bit of a hard task to cloth a whole product line in, DfX offers a selection of options to address single issues that can help the individual OEM gaining first ground in closing metal, component and other material loops (for further elaboration of DfX see Appendix 2I).

4.2 Defining a Vision & Objectives

In order with the methodological procedure stated in the start of this chapter, it is now possible to put out a shared vision for the future. OEMs are the ultimate subject to change in which they are the organisational driver for designing and manufacturing ICT products, while interdepend connections to other stakeholders might facilitate the desired change. Therefore, system initiatives for DRS and around EoLM are thus seen as possible strategic actions constituted around a varied set of stakeholders (e.g. government authorities, retailers, CROs and recyclers) in why the OEM is not the only actor in the scope to drive the transition towards closing the metal loops.

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[20] 'Eco-innovation' is a broad official term used particularly in the EU around: *"Any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development. This can be achieved either by reducing the environmental impact or achieving a more efficient and responsible use of resources"* (EC, 2013 [a]: 4).

By subtracting the theoretical discussion and conclusions in the previous chapter (cf. section 3.3), the circular production and design approaches plus added factors of technological innovations, defines the '***the vision'*** and holds the following:

- Create permanent incentives for continues technological development in product design evolving the sustainability profile on each product through eco-innovations that ultimately can meet full recovery of metals in the long term. In this light, it is outmost crucial to facilitate and secure information transfers in the post commercialization phase of a product life, to ensure full control of resources and retain value all the way back to the supply side of manufacturing operations. By seeking abundance in secondary raw materials production of metals and creating symbiotic relationships with stakeholders in the post-commercialisation phase of product life cycles, to confine and eliminate losses of resources fixed in obsolete products, and to finally close the metal loops.

Therefore, the three fundamental objectives in this defined vision can be outlined as:

- Ensure **resource and value transfers** through out the post-commercialisation life cycle of ICT products to close metal loops.
- Establish sufficient **information transfer** to build closed loop systems upon.
- Create incentives for **technological innovation** towards full recovery of metals.

'Geographical Scope': In the light of globalized markets and value chains for of electronic goods, its important to notice that it ultimately brings about heavy local e-waste creation both 'on' and 'from' mature markets (incl. Europe) (Robinson, B.H., 2009: 184). This situation expands the outlook from where actions could be taken (on the European markets) and on to getting metal resources transferred back to new manufacturing of products (closed loops) - hence a globalized market of scrap-resources (for processing) or for reuse markets overseas will possibly take place in order with the obligations in article 8, 10 and 11 to the WEEE Directive (2012/19/EU)[21].

This constitutes to a special situation. Scenarios analysed in this report is possible eco-innovative 'initiatives' that can be taken on a single national market, several markets or all markets within the European Union. Therefore, relevant stakeholders (producers or importers) could in theory also choose to ship out e-waste after collection for processing (e.g. to China) or to re-use markets overseas (if products are fully functional, in order with the WEEE-directive) and so the scope would expand to a global outlook. However, it is found necessary to limit this analysis to how such initiatives could be used as strategic actions and work around the EoL phase of obsolete products, handled and controlled inside the union.

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[21] Defines the juristical obligations for member states to ensure 'producers and importers' of WEEE live up to requirements set out in relation to 'proper treatment' (article 8 + annex VII), Shipment of WEEE (article 10) and recovery targets (article 11 + annex V).

'Time Horizon': Having an idea of the time horizon from which the vision and objectives should be met is another essential feature of the methodological procedure[22]. Developments in this particular industry and for general consumer electronic products are rapid - hence most manufactures update their product portfolio every year to stay competitive. This is shown by events like the annual international CES[23] exhibition for new innovations in consumer electronics. Additionally, most strategic rapports from international organisations work around the year 2020[24].

Another indication of a relative short-term outlook stems from the scarcity problem. High recovery targets (between 55-85% in 2018 depending WEEE category) set out in the WEEE Directive (2012) annex V, derives partly from the European Commissions recommendation to the Union in the year before (RMI, 2011)[25] around critical (non-food/non-energy) raw materials - establishing a strong focus on access, sustainable supplies and resource efficiency/recycling of metals (EC COM25, 2011: 13+15). All in all it is found suitable to analyse how initiatives could initialize desired change in a 10-year perspective.

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[22] J.B Robinson refers to long-term temporal targets in backcasting studies in the range of 20-100 years (Robinson, J.B., 1990: 1). However, in light of the scope it can be viewed quite difficult for almost anyone to estimate the ICT development even for the shortest suggestion and thus a 20-year period.

[23] Carried out by the international Consumer Electronics Association (CEA): www.cesweb.org (2013)

[24] For instance, the *Digital Agenda for Europe (EC, 2012 [a])* is part of the *Europe 2020* policy *(EC, 2013 [b])*, while GeSI has the *SMARTer 2020* strategy (GeSI, 2012). Also, the consultancy IDTechEx, known for strategic market research in high-tech industries, generally uses a 10-year ahead analysis target in their reports. That indicates rather fast implementation period for possible adoption of eco-innovative technological shifts e.g. for better recoverability. This means that the system changes that would follow are relative to general product innovation.

[25] The Raw Materials Initiative, under the European Commission

5. Sustainable Gap Analysis of the ICT Post-Commercialisation Product Life Cycle

In the last chapter the main objective was narrowed down and a vision was put forth. In correlation with this new vision and objectives for the future, there is a strong need to generate knowledge about the present. In order with the methodological procedure described in section 2.3, it is found suitable to search for sustainable gaps in the present ICT post-commercialisation product life cycle. By identifying these 'gaps' we should be able to see which *path characteristics* that would lead to viable circular and sustainability goals for the scenario analysis of new initiatives in chapter 6. The post-commercialisation product life cycle includes retail, the use phase, the collection system and finally processing (for recycling and recovery). The three pillars of the vision 'resource and value transfers', 'information transfers' and 'technological innovation' is thus used as the guiding principles to initialize gaps in the present system. As a start, it is found appropriate to elaborate the gaps in the collection challenge of general e-waste and obsolete ICT and analyse where mobile phones fits in this picture.

5.1 Challenges to Collection of E-waste in Europe & Denmark

When measuring the success of e-waste collection in general, the yearly outcome is compared to how much EEE (electric & electronic equipment) there is put to market that same year. This might sound strange considering that there always will be a time gap in the collection system - simply, that people are not expected to discard their electronic equipment the same year as purchased. Nevertheless, due to the very different lifetime expectancies of EEE products a more retrospective calculation method cannot be fully justified either and therefore, has not been used in the WEEE regulation until now. Insufficient data sets from the previous years (2005-2007) and the financial crisis in 2008[26] may distort the statistical picture. Therefore, the measure of collection in table 1 is calculated from the isolated datasets of 2010[27] on how much EEE that is 'put to market' versus how much that is 'collected'.

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[26] The EEE/WEEE data from 2010 corresponds very well or exceeds the level of 2007 slightly, thus it can be seen statistically that people were maybe changing patterns in 2008-2009 due to economic uncertainty. See data in Appendix 2J.

[27] Data from 2011-2012 has not been made official yet during the time writing.

EU27*	(1000 t)	Of ICT 'Put to Market'	Of All 'EEE Put To Market'
ICT collected	714	48,0%	7,4%
ICT collected from house holds	647	43,5%	6,7%
ICT put to market	1.489	100%	15,5%
WEEE collected	3.614		37,7%
WEEE collected from house holds	3.107		32,4%
EEE put to market	9.589		100%
Denmark			
ICT collected	18	67,5%	12,4%
ICT collected from house holds	18	65,7%	12,1%
ICT put to market	27	100%	18,4%
WEEE collected	83		56,2%
WEEE collected from house holds	82		55,7%
EEE put to market	148		100%

Table 1: *'WEEE & ICT Collection vs. Put to Market 2010'* – Data Source: Eurostat (See Appendix 2J). Data for ICT is represented by information on category 3 to the directive (Annex I): "IT and Telecommunications Equipment". *Data on Norway is incl. due to representation in the statistic from Eurostat.

With the new WEEE Directive (2012/19/EU, 2012 – Article 7), the overall collection target in the EU (in a given member state) are set to be 45% entering 2016 and 65% entering 2019. From now on, this has to be calculated and measured with the average of EEE placed on the market in the 3 preceding years - of a given member state. Alternatively, member states can make measurements with the amount placed on their market in the same year, but then they must achieve a higher total collection rate of 85% in 2019. Isolated for ICT, the new directive (ibid. - Article 11, Annex V) particular states that category 3 (ICT) and 4 must achieve a recovery target in 2018 of 80%, where 70% of the ICT collected must be prepared for re-use or recycled.

The actual national collection rates inside the EU are of course very different and rely on national waste handling and collection systems. As seen in Table 1, collection is significant higher in Denmark than the overall average in the union. Also, e-waste from households represents the vast majority, where companies only contribute with a low percentage ('collected' subtracted from 'collected from households'). For Denmark alone the objective is to increase the total collection of ICT from households by approx. 14 % before the end of 2018 given the total collection rate of 65,7%. To achieve full collection of ICT (100%), some 34% of ICT from households is missing in 2010 and is thus subject to new initiatives and regulation. Similar, the average collection of ICT from households within the union must increase with 35-36% before 2018 and thus 55-56% for achieving full collection. So the question that still remains is: what is successfully collected and what is not?

One answer is found around the widely recognized problem with low collection rates of so-called small WEEE (small obsolete electronic devices). This problem has thus also been targeted through a new order (article 5) in the WEEE Directive (2012/19/EU, 2012), where member states have to ensure free and easy accessible public collections points as a way to minimize small WEEE from ending in domestic waste streams. Retail stores with an area of more than 400m2 can be subject to collection of small-WEEE of up to 25cm, free of charge, if member states cannot justify that alternative or existing collection options are sufficient today (ibid. - Article 5 - §1-2). With regards to ICT this new order especially puts a focus on small devices such as mobile phones, mp3 players, hard drives and tablets (referred to as category 5 & 6 to Annex III)[28]. The problem of small WEEE, found in the domestic waste stream, is also related to other well-known problems around mercury-filled fluorescent light bulbs and alkaline batteries (The Danish EPA, 2013 [a] and ibid [c]) (Politiken, 2013). Another phenomenon is popular called the storeroom effect[29], where people are subject to store small obsolete devices and electronic gizmos at home (The Danish EPA, 2013 [b]: 89).

The obvious reasoning behind this overall problem, with small devices, can arguably be seen as a matter of size and convenience. This means, an old monitor that takes up a lot of storing space at home is thus more likely to be handed in at a collection site, than small devices that are easy to store in e.g. a drawer or end its life in the household bin. Therefore, the sustainable gap here is really how to create sufficient and 'easy-to-adopt' collection systems that can initialize the small e-waste devices that is found hard to collect in the present system. So collecting the products is the first sustainable gap to solve, since it naturally creates the foundation for any recycling activity at all. This is also where deposit refund systems is seen as interesting pathways to achieve better collection rates (Dawkins, et al., 2012: 33).

5.1.1 Collection of Obsolete Mobile Phones and the Use Phase

One of the main reasons why mobile phones were selected as an analytical object for this analysis is due to its representation among the devices in the small WEEE fraction. And so, when we look at mobile phones, the problem of collection smaller devices becomes clearer. In the consumer survey done for this study, the 290 respondents were asked, *"How many used or obsolete phones do you have stored at home?"* where the result is shown here in figure 10:

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[28] The WEEE categories will in the future be limited to 6 instead of 10 categories, with more focus on the size of the products. In this study the original 10 category system is used (defining category nr. 3 as ICT) in order with the transitional period from 2012-2018 (article 1 to the directive)

[29] In Danish, commonly called "pulterkammereffekten".

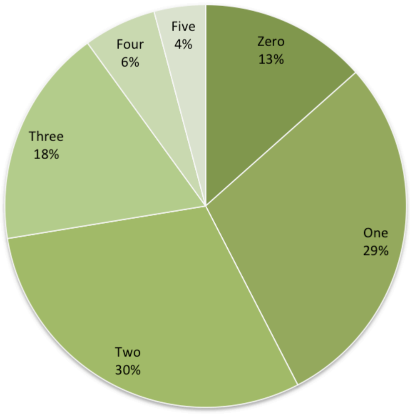

Figure 10: ‘Storage of Used or Obsolete Mobile Phones’ (Appendix 5A: Q10).

The data from the respondents’ equals an average of 1.86 phones/person stored at home. Some 13% reported to have none stored at home, while the vast majority (87%) have somewhere between 1 till 5+ stored. If this number were to represent the entire Danish population, it will equal approx. 10m uncollected phones[30]. An average weight 109 g/phone was measured on the 10 most popular phones sold in 2011 on the Danish market (The Danish EPA, 2013 [b]: 86). So in the matter of weight, this corresponds to approx. 1.1m t[31] in uncollected phones. This estimate on 10m so-called historical phones is equal to a recent study from Norway (Dag-Friis Baastad, 2012: 9), which can be justified as a comparison in terms of very similar country profiles and population size.

In addition the respondents reported to have stored phones were also asked to notify the main reasons behind. Here a selection of assumed reasons and choices were given. As pictured in figure 11, 41 % replied they kept old phones as a backup and 25% that they used them on e.g. holidays, travels and festivals. 17% actually replied they forgot that the phone(s) exited, while only 6% responded that they thought it was too complicated to hand it in at a recycling station from where they lived.

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[30] The Danish population was of January 2012 = 5,58m inhabitants (DST, 2013 [b]). With 98% possessing one or several mobile phones (DST, 2013 [a]) this equals (5,58 x 0,98) = 5,468m inhabitants to possible store obsolete phones at home. Calculated this equals (5,468 x 1.86) = 10.170.480 = approx. 10,2m mobile phones

[31] 10.170.480 x 0.109 (109g) = 1.108.582 kg = 1.108t = 1.1m t.

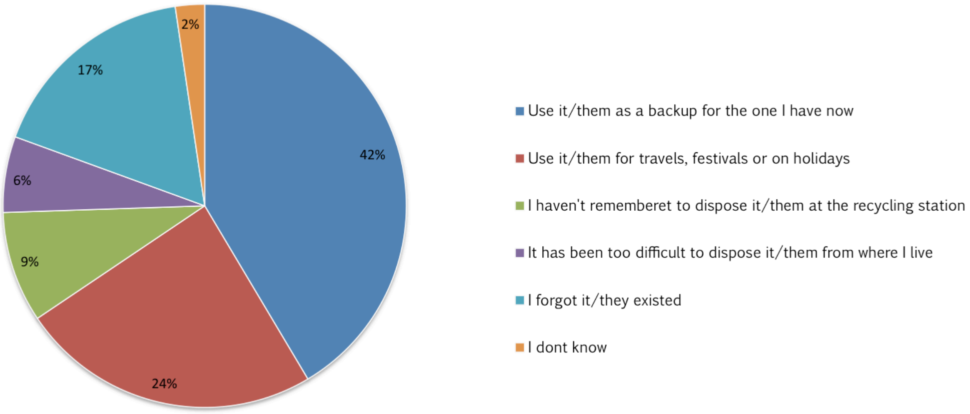

Figure 11: *'Reasons for Storing Old or Obsolete Mobile-Phones at Home'* (Appendix 5A: Q11).

This result tells us a couple of things. First of all that people usually like to keep their old phones as back-up for their new one, or, for using it in situations where they believe they can loose it easily, maybe need to keep battery life etc. If the reason for keeping them were to resell them on the second hand market they probably would have done so already.

It also tells us, that, it is really not because people lack real opportunities to hand in their old phones at a local recycling station or maybe through a take-back program. Increasing the possibilities for doing so, with no clear benefits, would therefore only have a possible effect on 15% of the respondents that either 'forgot to' or 'find it difficult to' recycle them. Therefore, it is questionable if more visible collection points or collection point that is easy-to-get-to like retailers, as initiated in the new WEEE Directive, would have an effect on the 34% of respondents that did not report a particular functional reason for keeping them stored at home.

Then finally and most importantly, it tells us that old phones keep a *personal value*[32] for most people much longer than the expected 2 years of lifetime that is normally estimated for mobile phones (Robinson, B.H., 2009: 184). A still functional mobile phone might not be a large asset, but it is still significant valuable enough for people to keep the devices longer. Therefore the personal use plus *keep phase* could easily double or triples its lifetime, to 4-6 years, before people finally dispose of the phone (some way and not necessarily the right way). Recent surveys state that people are actually expected to buy new phones on average every 1.5 years, where 40% of younger people between the ages of 16-34 years have bought new phones in the past 6 months (The Danish EPA [b], 2013: 89).

What could then be assumed is that people would hand it in 'at some point'. However, in Europe, a measure done by Nokia estimates only 10% of obsolete phones are collected today (ibid.). In another study done on

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[32] In some economic theory this is also referred to as "sentimental value"

Germany by the Öko-institut, states that only 5% were collected through official channels (Öko-institut, 2012: 40). The reality is that nobody really knows what the exact collection rate is, other than that it is very low. Since mobile phones have been commercially marketed from the mid 1990's (Dag-Friis Baastad, 2012: 9), many obsolete phones must still be stored in homes for an extended period of time. However, it is maybe more likely that a decent amount of phones purchased since the mid 1990's has ended their lives in domestic waste streams, were given to charity (for reuse overseas) or given/sold to retailers via existing take-back/buy-back options. The last option is also found likely to result in the shipment of old phones as reuse overseas (Dag-Friis Baastad, 2012: 10).

This means that a device like the mobile phone possess a great personal value to most people today, even after their initial use. Everyone in the world basically owns one[33] and many owns more (DST, 2013 [a]: 1) (Appendix 2F). Without doubt, mobile phones are a fully integrated technology in today's modern society, but mobile phones are also undergoing a large transformation to become the remote control of our lives (Sharma, 2010: 7). Due to the vast miniaturization of mobile computing devices it has increased the storage capabilities and access to cloud service from portable devices (Fischer & Smolnik, 2013: 1083). Devices like phones and tablets is therefore merging the ICT sphere, combining ones private, social and professional everyday life, giving access to a world of information and interaction (Fischer & Smolnik, 2013: 1082f). The barriers between the main tasks that a mobile phone is used to perform, in terms of calls and texting, can thus largely be seen as vanishing. Multiple other tasks like e-mailing, social networking, browsing, photos, video, GPS, online banking, gaming and as a mobile wallet (Sharma, 2010: 7), are just some of these newer abilities. These are also tasks that used to be done on personal computers or separate units like a video camera.

Why is this important? It is because, if we understand the place in society that these devices have, and how the so-called ICT revolution impacts the future, we also have a better chance at designing sufficient systems around them. The study of mobile, ubiquitous and pervasive computing is converging (Fischer & Smolnik, 2013: 1083) and so mobile phones are at the core here (Appendix 2F). If a comparison is made as to the importance of one's mobile phone to the importance of one's key to their house or their wallet, this would therefore be a fair reasoning for the prior statement. Because, the merging of properties is actually moving towards this kind of use, with the phone as your 'mobile wallet' or your 'electronic key' (BFE, 2012). This means, the importance that such an electronic device has on people's functional, professional and social lives is increasing. A summary of *presumption's* can thus be assembled towards creating collection and closed loop systems around mobile devices[34]:

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[33] 128% for developed countries 89% developing countries. 96% in total compared to size of the world population (ITU, 2013: 1).

[34] Presumptions should be seen as an attitude towards the present situation, which will be used to discuss the selected initiatives in the scenario analysis in chapter 6.

On the positive side:

- It may result in a continued merge of tasks, used to be performed on multiple devices, to a fewer set of devices – meaning less resources flowing through the system over time.
- That people would be more eager to secure their connectedness, by adopting services for repair and insurance of an always functional and up-to-date device at hand.
- That people to a larger extend maybe share old devices more with each other, to help e.g. a friend or family member in situation where they lost or broken their primary phone. This extends the utility lifetime of a functional product.

On the negative side:

- That people would hold on to devices, they in reality do not use much, creating long, unstable and unreliable time patterns between the use and EoL phase. At the same time, they continue to buy new devices on a fast and regular basis, while stored devices will mount up.
- That stored devices will loose their usefulness to people over time, thus finally become invaluable and maybe easier fall in wrong waste routes ones they finally get disposed.
- That people will need monetary incentives or receive significant extra services to be willing to return or dispose their obsolete phone the right way. Information and attempts to seek people's *'good will'* thus seem insufficient for getting the majority to dispose or return their obsolete phone through existing collection channels.

5.2 From Product Commercialisation to EoL

With the details from the previously section in mind on what the main challenges are to achieve full collection in the future compared to justified presumptions about consumer patterns and preferences, it is now possible to define the systemic conditions around the present post-commercialisation life cycle. As detailed in the methodological chapter (section 2.1) the focus has been assembled around what happens to the product ones it is put to market.

In this regard, it is found appropriate to view the post-commercialisation life cycle of an ICT product as five main stages. (1) It is put-to-market through several *'distribution channels'* (retailers). (2) Consumers naturally gain control of the products – *the use phase*. (3) The present *'collection system'* seeks to regain resources. (4) The obsolete products go to proper treatment through first *'pre-processing'* and finally (5) *'end-processing'* for recovery of metals. In this section we take a look and analyse the first three stages, while the last two, concerning processing (recycling and recovery), are assessed in section 5.4.1 and 5.4.2.

First step: OEMs launch different products every year that are distributed to various destinations including European retailers. The resources that was used to make a particular product, is now embedded in its interior, in why we can say it has a fixed internal resource value. In order to fulfil the European obligations in the WEEE regulations and the *extended producer responsibility* (EPR), OEMs optionally appoint a distribution channel (to be the so-called producer or importer), which then represent them in the particular member state (WEEE Directive 2012/19/EU).

In the interview with executive officer Johnny Bøwig from DPA-system, he generally explained; the easiest way to understand who actually has the EPR (responsibility for take-back of WEEE) is to look at where the first turnover is created, in which that company becomes the *producer or importer* (Bøwig, Appendix 5B, 2013: min. 49). This means, that an OEM might establish an affiliated company domestically or regionally appointed to handle the further sale and thus recycling program for separate amounts of EEE put to market. As Bøwig explains, the OEMs do not need to hold track with their affiliate companies for business-to-business (B2B) trades done between OEM and separate retailers. This means the EPR will first come in to force when the product is actually sold to an end-user on the market (ibid. min. 51-52). This makes it more flexible for the companies to distribute through several channels affiliated retailers (type 1) and external retailers (type 2). As an example; a mobile network operator (MNO), which sells a given amount of a mobile phone line through their retail and web-stores, will have the EPR for that given amount. Meanwhile, if there is an affiliate retailer of the mother company, which might also sell from own stores, they would also have the EPR but for that amount. Basically, the companies that together sell a particular device on a given European market decide between themselves who has the EPR for the amount they each sell. The 'responsible' companies register at the national WEEE system body (in Denmark it is DPA-system) and usually organise their take-back program through a collection and recycle organisation (CRO).

Second step: the product is sold to a consumer, who posses the product until it becomes obsolete and then they might return it to a collection point. Some retailers, MNOs, have established buy-back arrangements, where they economically compensate for used and fully functional phones, but only if the owner buys a new phone plus a subscription to that operator[35]. What happens then with the phones is not totally clear, but they are very likely shipped to second-hand markets overseas for re-use (Dag-Friis Baastad, 2012: 10).

As noted in section 5.1 losses occur in the use phase, when small devices are found in wrong waste fractions (e.g. domestic waste). Consumers might also choose to sell or give their product to second hand markets (e.g. sell through eBay, give to charity, or to take-back/buy-back for "reuse" channels). Obviously regular theft or scavenging from local collection points can also cause the product to leave the controlled life cycle, though the scale is unknown.

Third step: Collection systems. The CRO's role is to ensure that the WEEE is collected from the established collection sites and send to an authorised treatment facility. Thus, the actual role of the CRO is very administrative. As Henrik Jacobsen from the Danish CRO 'El-retur' explained, they manage the WEEE by outsourcing the duty to trucking companies, which pick up the waste fractions at main collection sites. Currently, the collection logistics are arranged on a 48-hour notice (Jacobsen, Appendix 5B: min. 8-9). In

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[35] At least two of the MNOs on the Danish market, Telia and Telenor, both have such arrangements. Telia calls it "4green" (Telia, 2013), and Telenor's is called "byt til nyt" (Telenor, 2013) which can be translated to: trade for new.

Denmark the collection is arranged around central collection sites established by the municipalities, where in other member states retailers can act as collection sites.

So, the value exchange and fulfilment of the EPR is based on a simple and practical service fee system. El-retur does this around a *pay-as-you-sell* deal, where they charge registered companies in the collection scheme for the amount they put to market. This is done on a monthly basis. Jacobsen explained that this type of system requires a large equity capital, since they have to pay service fees up front, which makes reasonable sense. However, Jacobsen explained that El-retur had a no information disclosure, so no estimates was given in terms of size of fees, monthly expenses and so forth (ibid.). Therefore, it is also reasonable to question if the financial capital coming in from selling the e-waste to recyclers is larger than the cost to run the administrative and logistical system of a CRO. Here it should be mentioned that El-retur is a non-profit organisation working on behalf of its members (El-retur, 2013).

The opposite option is thus to make a *pay-as-u-scrap* deal (The Danish EPA, 2012: 26), but here the CRO is forced to control and expect what is coming in at the collections sites, ensure sorting in brands, weight and fractions, to eventually be able to charge the responsible member companies for a certain amount. The other way around, with the pay-as-you-sell system, the CROs only have to ensure proper recycling for a mixed WEEE-collection of 10 weight-based categories, and so this last phase before collected e-waste gets treated is being subcontracted, basically as it is now.

Today, a pay-as-u-scrap system would naturally generate much higher costs for the CROs and thus the member companies, but would also be able to establish control of the valuable resources. However, the lack of information in the present system forces these private stakeholders, economically, to seek the first option. If the information to re-collect obsolete products were present (much like in the case of wholesale), the CROs would be able to decide, on behalf of there members (including OEMs), where to send a given e-waste fraction to get the most resources recovered and value return. Therefore, the present gap is that practically all information about the product is lost as it is sold to private consumers on the market.

As Bøwig explains, individual producer responsibility is also an option (through the WEEE regulation), but the complexity in establishing such systems and costs for a 'producer or importer' is regarded as economically unattractive, which is why none of the OEMs use it today and instead operate under collective schemes (Bøwig, Appendix 5B: min. 22). Bøwig also explained that when the WEEE Directive was first established, everyone saw e-waste as a cost, and why now, together with fast growing metal prices (cf. section 3.2), every stakeholder in the recycling sector also knows now that it is a valuable resource. (ibid. min. 19).

In this regard Bøwig also noted another important problem in the present system, where what they termed "grey waste flows" had been found developing fast in recent years. According to Bøwig, the grey waste flows are when unauthorised collection is happening apart from the juristically bound system, in which private companies or individuals illegally buy e-scrap from private persons or other companies to process or sell on. It thus may result in recycling somewhere, but it will not show up in the official statistics. In this perspective the system has backfired, in why Bøwig see it as a paradigm shift that has taken place in recent years, where the whole regulation system, set out through the WEEE Directive, is based on e-waste as being a cost. Now problems working against the system have emerged, since the opposite situation is the case and profits can be made on selling e-waste (Bøwig, Appendix 5B: min. 25-27)

In DPA-system they had heard that, some CROs now choose *not* to charge fees from their member companies anymore, because their earnings proceed the costs, meaning that there is positive coverage today on most of the WEEE fractions to pay for collection costs (ibid. min. 1-3 + 19-21). This means that CROs practically work alone on behalf the members, ensuring that their juristically obligations are fulfilled. So, to stay non-profit, CROs may use the sales revenues to pay for their administrative and logistical costs, resulting in a situation where OEMs seems fully disconnected to the EoL phase, since no necessary connection is needed of them.

It seems as if no valuable incentives for better resource use gets created. In this regard, Jacobsen also explained that their cooperation with their members was very limited and so they didn’t believe there was any need to talk with their members about sustainable product development or technical aspects of EoL management. He believed, corporate resource strategies were not something that happened domestically, on European markets, but somewhere else in the world by these multinational corporations (Jacobsen, Appendix 5B: min 25-27).

As noted previously, the opportunity to take-back and resell obsolete but functional devices as re-use, such as mobile phones, is something that happens before they enter the official collection. Jacobsen explains that they practically did not see any mobile phones in the e-waste streams collected through the normal channels. He expected that a reasonable amount of these phones went back to the retailers through their buy-back arrangements (Jacobsen, Appendix 5B: min. 22-23).

The discussion of “re-use” markets can be long and manifold, but if, for example, a mobile phone is shipped off to a second hand user in a developing country where the product maybe can get a reasonable extended life, studies indicate that some developing countries, with an active informal waste sector, collect as much as 80-90% of the country’s e-waste. However, dangerous and inefficient backyard recycling practices are common here and a maximum 25% of the valuable metals such as Gold and Copper are recovered. Compared to a state-of-the-art end processing plant in Europe with 95% or above recovery rates for precious metals, the picture is still more or less equal due to the low collection rates that unfortunately exist in the developed countries (UNU, 2012) (The New York Times, 2013). Besides fully loosing track of the resources and maybe coursing environmental and dangerous health problems somewhere else in the world, additionally GHGe from shipping old phones for re-use overseas also looks questionable in a life cycle perspective.

The important point here to be notified as a sustainable gap, is if used ICT devices, such as mobile phones, leave Europe as either approved re-use products (in order with the WEEE Directives article 23) or through unauthorised e-waste streams, it also leave the controlled recycling and recovery practices inside the union. Thus, building circular and sustainable business models and collections systems through new initiatives can then be expected to become very complex and unmanageable.

As a summary of the identified sustainable gaps, a flow diagram of the post-commercialisation life cycle is pictured in figure 12, were possible resource losses are shown for the first tree stages:

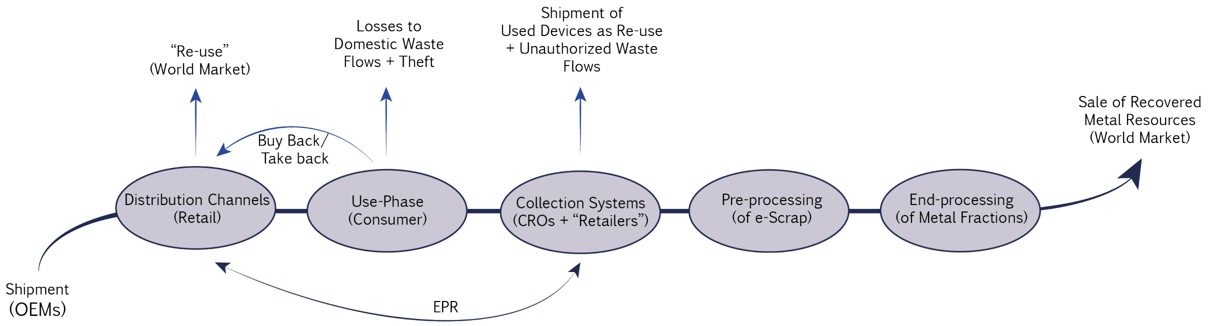

Figure 12: *'Losses From Distribution to Collection'* - In all the first tree stages, resources in obsolete products can leave the European market by being shipped out for re-use, or, get lost to other waste flows. The EPR is maintained between several distribution channels and usually the CROs who are entitled to ensure proper treatment of the collected WEEE in the end. However, here information gaps are created after the sale of devices and since no overall need or interactions is found between stakeholders around the EPR obligations. Some value seemingly gets stuck at CROs and is not necessarily transferred to either their members (e.g. OEMs) or the recyclers further down the line (which by default base their business on handling the waste). Technological innovation for better recycling and recovery is thus unlikely to take place, since no information or value gets naturally transferred between the EoL phase and the OEMs. In the first stage, it is also important to notice that there is a long distance between OEMs (designing the products) and the actual retailers (selling the devices), even if its affiliated retailers - hence another couple of steps between the consumers and the mother company can be found here.

5.3 Metal Resources & ICT

Before we can go on and analyse gaps in the stages of pre-processing and end-processing, it is found appropriate to discuss and elaborate details on metals resources that are fixed in the interior of the products. Additionally, some basic understanding of the relationship between metals is needed to understand the dynamics in the processing stages.

In a typical mixed e-waste fraction we find ferrous metals to be the most common raw materials and accounting for approx. 50%. Plastics are second with approximately 21% of the e-waste, while 13% of the total is non-ferrous metals, which includes precious metals (Cu accounting for 7%). (Widmer, et al. 2005: 446). Many ICT devices have a lot more plastic content, for example, casing, boards, insulators and substrates, to reduce weight and costs, but are high on precious and special metals. This is why they provide a solid economic base for general processing of e-waste (Hagelüken & Meskers, 2010: 167f). In this regard, mobile phones have the highest concentration of valuable metals compared to their weight and volume (Hagelüken & Corti, 2010: 3).

To get an overview of the metal recourses ICT contains, we have to take a look inside. Unfortunately, OEMs are not obligated to share information about the source of the elements in their products (Friends of the Earth, 2012:

6)[36]. While tracing the resources can be a difficult task but not impossible, OEMs should be expected to know exactly what elements they use in their product portfolio and hopefully where they come from, regardless of the hundreds of connections that can be found in their supply chain. Studies on metal supply chains for electronics have recently been conducted by Young & Dias (2011) and the Resolve (2010) (also see Appendix 3D).

ICT appliances and devices share some basic characteristics and components, which is used to determine the content of elements in a waste fraction (UK Environmental Agency, 2011: 75). ICT products, as well as other electronics all incorporate a mix of main components like: casing, battery, display and printed circuit boards (PCBs). A list and description of typical and main components in ICT is assembled in Appendix 2B.

In almost all of these electronic components we find *metals*. Before an element can be used in its pure form as a metal it has to be extracted from its crystallised form in nature as a mineral (Appendix 3D). Some elements found in higher concentrations are usually called metal ores (but contains impurities too). The mining and extraction of metals is what provide the industries with raw materials for producing e.g. mobile phones, notebooks and tablets. Metals usually have high conductivity of both electricity and heat, thus mainly used in electronic equipment for their conductive or semi-conductive (and other) properties as solids in room temperature (Appendix 2C-2E). Due to their chemical and physical properties they are separated into groups in the periodic table of elements such as transition, post-transition and lanthanide metals (Lide, 2009: 51).

However, metals utility is defined by various other means than their simple chemical placement among elements. Therefore, it is sought to make an example. Iron (Fe) is the fourth most abundant element in earths crust. Though this prehistoric element reacts and corrodes easily in pure form it is found heavily used to build our society today, in alloy form with carbon and other metals (Lide, 2009: 4-19) – just think of steel manufacturing for cars, bridges, buildings and so forth. However, it is still rather inexpensive due to a high supply for the demand and pretty efficient recycling streams (recycling rate at 70-90 % according to UNEP, 2011: 30). The present settlement price for steel was traded at 130 USD/t (LME, 2013). At the same time, Silicon (Si) is the second most abundant element making up 28% of earth's crust (Lide, 2009: 4-10), but used in the high-tech semi-conductor industry to make e.g. microchips for all ICT products. This makes this metalloid special and rather priceless.

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[36] However for mobile phone companies, a lack of corporate disclosures and general transparency is not necessarily the case for every OEM. For instance, Nokia has provided a brief 'eco-profile' of many of their products, has fully restricted hazardous substances and a profile to work openly with their supply chain (Nokia, 2013 [c]).

The silicon-dioxide (SiO_2) we all know as *sand* (or silicate) goes through some ultra-complex of metallurgical refining steps, to become 99,9999999% pure or just mono-crystalline[37] (Hagelüken & Meskers, 2010: 180) (TechRadar, 2009). Just plain silicon-metal (98,5% purity) was traded on an average of 119 USD per kg as of June 2013 (USGS, 2013). This means that it is nearly 1000 times more expensive than steel, even as a lower grade product. Moreover, ultra-pure Si is not only used in microchips in electronics, but also for other important and also growing markets such as solar cells (PVs) (Hagelüken & Meskers, 2010: 193).

It tells us that; an element's value to society is not only determined by its abundance in nature (as an immense resource stock) but also other main factors: besides its physical and chemical properties, its specific use, the labour and manufacturing costs put into refining it, the investment in technology and production facilities to make it into a high-tech commodity all have very important parts to play. Put in another way; it becomes extremely valuable and thus considered a special metal (Hagelüken & Meskers, 2010: 165), even though it is in reality the most abundant elements on earth only second to oxygen. The normative reasons for recycling it would simply be by its appliance in almost all electronics today. But this is not the case. Any recycling of Si was rated '*insignificant'* by the US geological survey in 2012, hence the Si resources are found '*ample*', and therefore not important enough to quantify (USGS, 2012: 144). The notion is that if the material is so abundant then it is not even considered for recovery. And so in combination with apparent very small amounts of actual Si ending up in each ICT device[38], and the technological complexity in how it is actually put there (in a PCB soldered microchip), maybe makes it more or less uneconomical to recover – especially if the systemic foundation is not there to close the loop. If we do not consider the recycling that actually takes place inside the industry from production scrap (cut offs from Si ingots/wafers in microchip production), the elements embedded in products, soon to be e-waste, can largely be seen as an *expected loss*. This mean it would only and may be considered important to reclaim in the presence of scarcity and thus approaching new R&D for technical and economical recoverability. Not saying silicon is the most important metal to recover from ICT products, right here right now, but it reviles a main gap and a basic paradox in our economic and technical use of metal resources – simply, it is very valuable but not sought to be recovered. Some might claim that there could be other important reasons for recycling and recovering Si, for example reducing the massive GHGe in the metal production phase of the lifecycle[39]. Therefore, a sustainable gap can be expressed by the need for socio-technical systems around waste products that creates a technical foundation and nourishment of technological innovation to recovery practical every finite resource – even if this resource is only used on the smallest scale.

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[37] Known as mono-crystalline electronic grade Si. Only the best silicate, without too many impurities, can be used and is therefore mined by quarrying. The following steps of ultra-purifying the semi-metal include; refining to metallurgical grade Si, then polycrystalline Si and lastly mono-crystalline Si before it can be cut into wafers and the end production of microchips. (TechRadar, 2009) (Intel, 2012)

[38] The weight of a single chip without package It is not listed in the articles from TechRadar (2009) and Intel (2012), but an older measurement from a LCA study uses 0,004 pounds per chip corresponding to approx. 2g (Enviroliteracy, 2008)

[39] As a comparison; 64-69% of lifecycle GHGe are in the making metallurgical grade, polycrystalline and then mono-crystalline Si, for solar-cell production. Data is taken from a LSA study of PV-cell production (Fthenakis, 2012: 4).

However, to go a step further, we can say that metals are categorized in industrial terms from their applied technical function, scale of use and supply. In general, industrial metals and semi-metals (metalloids) are defined as; either *base, precious* or *special metals*[40]. To further discuss the complications in the pre-processing and end-processing stages of the EoL phase in section 5.5 and find the sustainable gaps in these processes, we need get a basic understanding of what these metal groups provide to the end products.

5.3.1 Base Metals

Metallurgical smelting and refining technologies have been developed over centuries based on metal families, geological distribution and abundance in nature. Therefore, there are 5 main *metallurgical routes* today; copper (Cu), lead (Pb), nickel (Ni), aluminium (Al) and iron (Fe) (Hagelüken & Mesker, 2010: 186). These are all seen as *base metals* or sometimes also referred as 'carrier metals' as they are thermodynamically starting points (collectors) for metallurgical smelting and refining processes. Base metals also include other elements such as tin (Sn), cobalt (Co) and zinc (Zn) (ibid, 2010: 185) (UNEP, 2013: 30). They are in general relatively 'inexpensive' but very crucial to society as building blocks for industry and infrastructure. However, some of them corrode or oxidize, which can be problematic for the interior of high-tech electronics such as ICT. They also have very different properties of density, weight, melting points and hardness. While Iron and Aluminium are widely used in general all EEE, Cobalt and Tin is found in high concentrations as connector materials in ICT devices (Appendix 2C) (UNEP, 2013: 217). Some would regard Cobalt and Tin as special metals due to their scarcity, but here they are grouped as base metals according to UNEPs definition (UNEP, 2011: 7) and because of their rather extensive use in ICT products. The cheaper base metals logically make up the larger amount of metals in ICT. For instance; Iron is used for structural purposes, in casings, magnets, batteries and PCBs. Likewise, Aluminium is used as a structural material, in casings and PCBs, but also in connectors (UNEP, 2013: 217). Examples of selected base metals properties and uses are assembled in Appendix 2C.

5.3.2 Precious Metals

The next group of metals in ICT and electronics is precious metals (PMs)**.** Precious metals are widely recognized to be gold (Au) and silver (Ag) plus the platinum group metals (PGMs), which include platinum (Pt), palladium (Pd), iridium (Ir), rhodium (Rh), ruthenium (Ru) and osmium (Os) (Swanson, 2006: 1). Precious metals only make up relative small amounts in ICT devices and thus can be measured in ppm or g/t, in general, for approx. 0.5% of the total weight in a mobile phone or on a computer PCB. Nevertheless, these precious materials *"contribute to over 80% of the value, followed by copper - 10–20% of the weight or 5–15% of the value"* (Hagelüken & Mesker, 2010: 188). As an example, the fixed resource content of Gold in single mobile phone is calculated to be around 100 times greater than the amount of Gold mined from virgin ore, compared to

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[40] Some also use the definitions; 'major' and 'minor' metals.

weight and volume (Appendix 3B). This also means that a general calculation could be made setting the fixed Gold value at approx. 1.2m € per 1 million collected phones (ibid.).

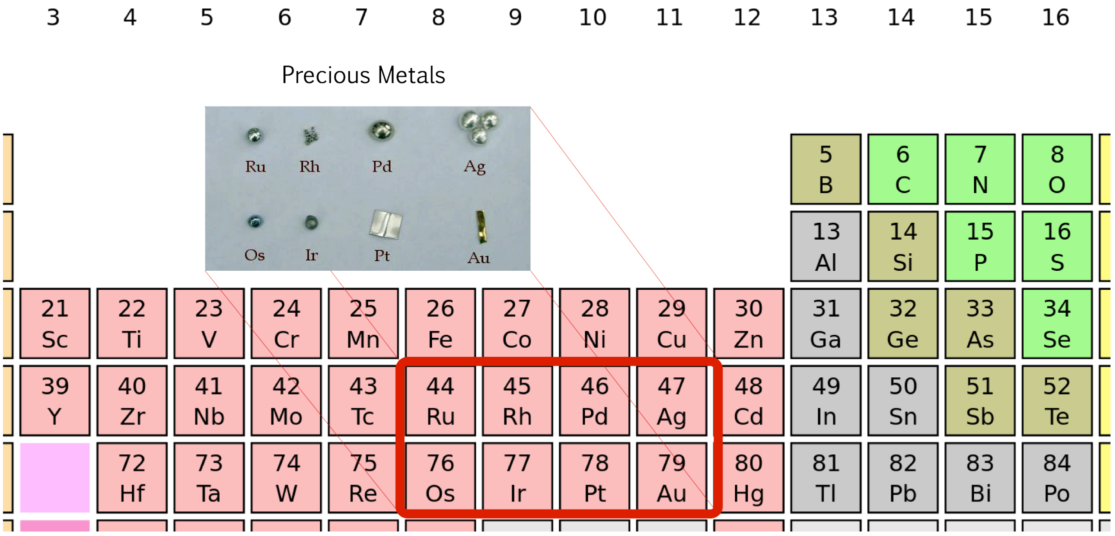


Figure 13: *'Precious Metals'*. Picture of precious metals reprinted courtesy of Tomihahndorf (CC).

Together with copper these metals can largely be seen as the economic drivers of WEEE recycling (the paying metals), and why most recycling companies focus solely on them (Hagelüken & Mesker, 2010: 188). All of them are relative very scarce metals, contributing to make them so-called *precious*. PMs are mainly used in electronics due to their unique and superior properties, such as; high conductivity, no corrosion and no oxidization (Swanson, 2006: 24). A description of PM properties and unique uses in ICT products is assembled and found in Appendix 2D.

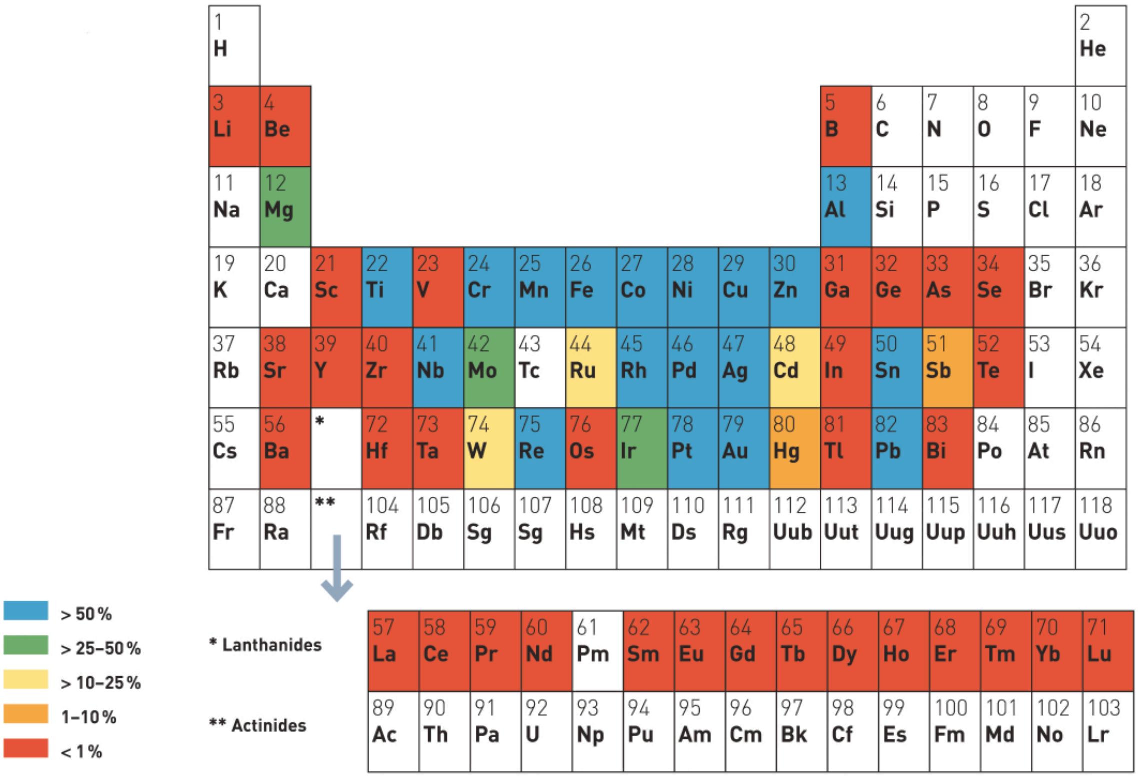
5.3.3 Special Metals

These elements, as a whole, belong to no particular group of metals, but simply refer to elements, which are used for their special and unique properties and are often rare (some of course more than others). Some special metals like rare earth elements (REEs), indium, gallium and tantalum are crucial to make today's high-tech electronics. This also means that for many of these elements, new substitutes could be view unlikely to be found in the foreseeable future and maybe never to be found. Nevertheless, these are generally applied in various but usually low concentrations to give ICT products *special* abilities and crucial foundations for product functionality such as in super strong magnets, as dopants, in the making of heat sinks, or to make transparent conductive layers for touch displays (Appendix 2E). A description of special metals properties and unique uses in ICT products is assembled and found in Appendix 2E.

5.3.4 The Critical Resource Situation for Elements Used in ICT

The majority of elements used in ICT as described above and in appendix 2C, 2D and 2E, revile some basic facts about the present lifecycle; where the uses of different technological metals are extensive and extremely complex. As an example; over 30 elements are used in a desktop computer (excluding screen) (Hagelüken & Mesker, 2009: 528). A mobile phone contains way over 40 single elements (UNEP, 2013: 221). So, if we were to look at the recycling rates for most of these elements, some general perspectives can be taken which help to reveal gaps for a sustainable ICT product lifecycle.

In 2011, UNEP assembled recycling rates of 60 metals and their common EoL recycling rates in society, including all metallic waste streams (shown as Figure 14). The metals selected in the UNEP study, could in general be viewed as the common industrial metals and thereby most of the above-mentioned technical metals, used in ICT and thus mobile phones, are represented here.



1 H																	2 He
🟥 3 Li	🟥 4 Be											🟥 5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	🟩 12 Mg											🟦 13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	🟥 21 Sc	🟦 22 Ti	🟥 23 V	🟦 24 Cr	🟦 25 Mn	🟦 26 Fe	🟦 27 Co	🟦 28 Ni	🟦 29 Cu	🟦 30 Zn	🟥 31 Ga	🟥 32 Ge	🟥 33 As	🟥 34 Se	35 Br	36 Kr
37 Rb	🟥 38 Sr	🟥 39 Y	🟥 40 Zr	🟦 41 Nb	🟩 42 Mo	43 Tc	🟨 44 Ru	🟦 45 Rh	🟦 46 Pd	🟦 47 Ag	🟨 48 Cd	🟥 49 In	🟦 50 Sn	🟧 51 Sb	🟥 52 Te	53 I	54 Xe
55 Cs	🟥 56 Ba	*	🟥 72 Hf	🟥 73 Ta	🟨 74 W	🟦 75 Re	🟥 76 Os	🟩 77 Ir	🟦 78 Pt	🟦 79 Au	🟧 80 Hg	🟥 81 Tl	🟦 82 Pb	🟧 83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Sg	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uug	115 Uup	116 Uuh	117 Uus	118 Uuo

* Lanthanides	🟥 57 La	🟥 58 Ce	🟥 59 Pr	🟥 60 Nd	61 Pm	🟥 62 Sm	🟥 63 Eu	🟥 64 Gd	🟥 65 Tb	🟥 66 Dy	🟥 67 Ho	🟥 68 Er	🟥 69 Tm	🟥 70 Yb	🟥 71 Lu
** Actinides	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

🟦 > 50 %
🟩 > 25–50 %
🟨 > 10–25 %
🟧 1–10 %
🟥 < 1 %

Figure 14: *'End-of-life Recycling Rates for 60 Metals'*. Illustration reprinted, courtesy of UNEP (2011 [b]: 19). This table shows global average recycling rates for post-consumer metals, and shown as functional recycling, meaning that the physical and chemical properties of an element has been retained and can enter new life-cycles (e.g. in new products). White boxes indicate either no data, or estimates where available or that it was not part of the original study (ibid.).

Figure 14 shows semi-positive recycling indicators for most of the base and precious metals. Nevertheless, it is far from the whole picture and there are several identifiable gaps revealed. In reality e-waste suffer from significant lower recycling rates. Precious metals in e-scrap are recycled at <15%, meaning that most of them are lost in the flow of recyclates. The picture gets distorted due to, for instance, high recycling rates of >90% in the jewellery industry (UNEP, 2011: 32). The jewellery industry also makes up the largest end-use for gold, for example (Norgate & Hague, 2012: 54). At the same time most special metals also have ultra low or practical non-existing recycling rates. However, the base metals are, in general, all recycled at high rates, but only if they enter the right WEEE treatment process. This is if they enter the right metallurgical cycle (elaborated further in section 5.4.2).

The remark here is that precious and special metals might not be of great concentration in the final product, but are vital technological composites in ICT products today. Even though losses occur at every stage of the lifecycle (e.g. mining, metal production, refining, product manufacturing) the largest gaps that appear in a sustainable analysis are due to non-existent or inefficient recycling of EoL products (Hagelüken & Mesker, 2010: 163). The challenge comes from complex material compositions in the technological components and low concentrations of metals that are dispersed over several parts of the final products (ibid.). This creates an enormous challenge for making these products sustainable in the future – to close the loop.

From a more societal and economic point of view, the picture unfortunately does not look brighter. Between 2009-2010 a working group under the European Commission's subdivision 'Enterprise and Industry' assessed important industrial raw materials. The aim was to provide a list of critical raw materials for Europe based on a matrix of supply risks (e.g. geopolitical stability, geological scarcity) and economic importance for European businesses and industries (EC, 2010: 5). As seen in the figure below taken from the report, the list consists of 12 single elements and minerals: *Be, Co, Ga, Ge, In, Mg, Nb, Sb, Ta, W, graphite, fluorspar, + 2 the two element groups REEs and PGMs*. Most of the elements here are not only critical raw materials in a European perspective but critical elements used in ICT, hence largely represented by the vital precious and special metals.

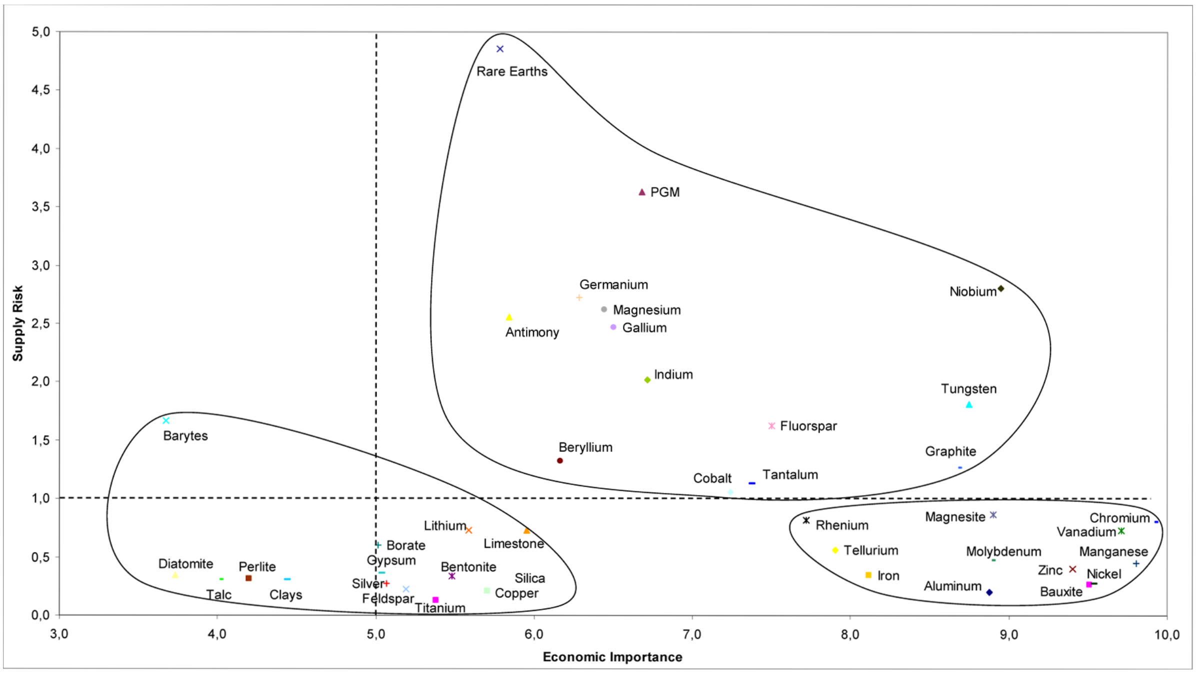


Figure 15: *'EUs critical raw materials'*. Illustration reprinted, courtesy of the European Commission (EC, 2010: 34)

5.3.5 Sustainable Efforts by OEMs in Relation to Resource Use

Since 2006 Greenpeace has rated the OEMs of consumer electronics in their yearly *Guide to Greener Electronics*. Nokia is the only OEM of all the mobile phone producers that scores above 5 (5.4) out of 10 points here in the latest edition. Apple, Samsung and Sony, which are the next mobile phone producers in line, all enter the list with around 4-5 points. So what does this rating mean? The companies are evaluated on their ability to set targets, provide transparency and meet goals within: *energy* (e.g. GHGe, energy policy, RES supply to operations), *products* (e.g. hazardous substances, energy efficiency, use of recycled plastics) and corporate *operations* (e.g. policy to avoid conflict minerals, management of chemicals, providing take-back programs). The only part of the survey they all score high points in, are for their development in *product energy efficiency* (Greenpeace, 2012). It clearly shows signs about the sustainable efforts that the largest OEMs of mobile phones put forward and prioritize today. Energy efficiency in products is, when it comes down to basics, an important competition parameter for products that use a lot of energy for streaming content on the run. Which is likely to be something consumers will require more of in the promised digital future of ours (Appendix 2G). Nevertheless, the product life cycle is not something the OEMs seem to be very engaged in today, scoring zero to low points here, even though Samsung gets credit for their general provision of product spare parts and life extension applications (Greenpeace, 2012). What is also evident about Greenpeace's survey is that they, as an investigator, actually do not focus much on the materials used in products and the recyclability of such.

When looking into mobile phone OEMs like Samsung, Nokia, Apple, Sony, HTC, RIM and LG, many of them provide so-called corporate social responsibility or CSR-reporting's, but very few link their "goals" to specific products, in terms of providing clear and transparent environmental and social profiles in their product portfolio. Nevertheless, three of the main OEMs (Nokia, Sony and Apple) have been found to have more product specific social- and environmental information publically available.

Nokia provides good and firm descriptions by making an *eco-profile* for every device in their product portfolio. Sony wishes to do the same, but lacks in providing information about the latest devices on the market. Apple has a much more narrow product portfolio but has provided what they call an environmental report for all their products. Therefore, three product profiles where selected and reviewed, including: Nokia *Lumia 920*, Sony *Xperia Z* and *Apple iPhone 5*[41].

In general, besides describing how they live up to the chemical requirements in e.g. the RoHS-directive and the energy-efficiency requirements in e.g. the Eco-design directive, none of the product profiles, have more than a brief description of elements used and some only provide a percentage on metal content. None of the profiles

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[41] Nokia Lumia 920 – Eco-Profile (Nokia, 2013 [a]), Sony Xperia Z, Environmental Declaration (Sony, 2013), and Apple iPhone 5, Environmental Report (Apple, 2013[a]). All put to market in late half 2012 – early half of 2013.

contain a clear description of how they wish to go about recycling or seeking recovery of the elements used through the actual product design (e.g. applying specific design concepts). Additionally none of the profiles contain information on spare parts either. However, Apple writes that the iPhone 5 has a recyclable aluminium enclosure (casing), but do not explain why it is so. Here it should be mandatory to ask: How is it more recyclable than any other material? How does this enclosure make it *easier* to recycle?

Therefore, the opportunity for future progress on resource efficiency seems pretty open. Furthermore, since both Apple and Nokia show to be aware of the major GHG emissions embedded in the production processes, such emission abatement could be found beneficial as greening product portfolios. As an example: Based on product specific LSAs[42] on GHGe, Nokia set an estimate 68% (Lumia 920) while Apple estimate 76% (iPhone 5) of emissions stems from raw material extraction to final product manufacture. Additionally, Nokia sets an overall estimate of GHGe to 74% occurring before final product assembly in their general product portfolio (Nokia, 2013 [b]). From those two product profiles, the OEMs estimate the usage to respond to 17-18% of the GHGe (based on 3 years in use) and finally only 1-2% of GHGe is found around recycling and processing. This means, OEMs have yet to address the recycling and recovery capabilities of resources in their products, but they might also be able to eradicate major GHGe impacts from doing so and see it as a directly result.

5.4 EoL Processing - Recycling and Recovery of Finite Metals

This section will examine the recycling practises that take place in the EoL phase and what the challenges are to those whom actually handle the e-waste (also see the last two steps in figure 12). From this point of view, it should be apparent as to what could be done differently to eventually make high and valuable metal yields become a reality. In this case, the Interviews with Simon Rasmussen of the Danish pre-processing plant DCR-Environment and Dr. Christian Hagelüken from Umicore - Precious Metals Refining Belgium/Germany will be used to give a more practical understanding of the processing of e-waste and the obstacles they see and experience.

5.4.1 Pre-processing

When the e-waste enters the EoL phase after disposal on a collection site or point, it is usually taken to a pre-processing facility. The companies providing this service are directly paid by the CROs while they also earn by further selling the processed scrap to smelter and refineries downstream (end-processing). The e-waste from Denmark is of relative low volumes reflected by the size of the country and no end-processing facilities are found domestically. This is normal for most of Europe, where some companies like Umicore specialize in metallurgical smelting and refining and can import huge amounts from all over the continent. Therefore, the e-scrap fractions are sent to end processing in e.g. Germany after this first pre-treatment. In this case, DCR-environment has been contracted by El-retur to handle waste from all over Zealand, Denmark.

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[42] Both LSA methodologies on energy use and GHGe is based on ISO 14040 and 14044.

Pre-processing is mainly done in order to sort materials or different components into the correct treatment and recovery processes using different liberation and sorting techniques for an overall separation (Meskers, et al., 2009: 530). Pre-processing of the waste products is also done in order to assure that objects containing hazardous substances[43] such as capacitors and batteries are removed and carefully treated. A mixture of manual dismantling followed by shredding and crushing, is used in this process (ibid.). At the DCR plant, they sort out displays and screens but do not run them through the processing unit, as Rasmussen describes, to ensure that his workers are not exposed to the many hazardous substances those objects possesses. Therefore DCR-environment have outsourced that fraction (Rasmussen, Appendix 5B, 2013: min 7). Products like 'white goods' are not treated by DCR-environment either, as the facility is designed to handle smaller consumer electronics (Rasmussen, Appendix 5B, 2013: min 9).

The four end-products (granulated e-scrap fractions) they were able to create, included: *'high-content ferrous metals'*, '*high-aluminium'*, *'high-plastic/low non-ferrous'* and *'high non-ferrous/low plastic'*. This does not mean clean fractions, but is nonetheless used to express the major content of each fraction. The processing steps[44] used, are presented in figure 16:

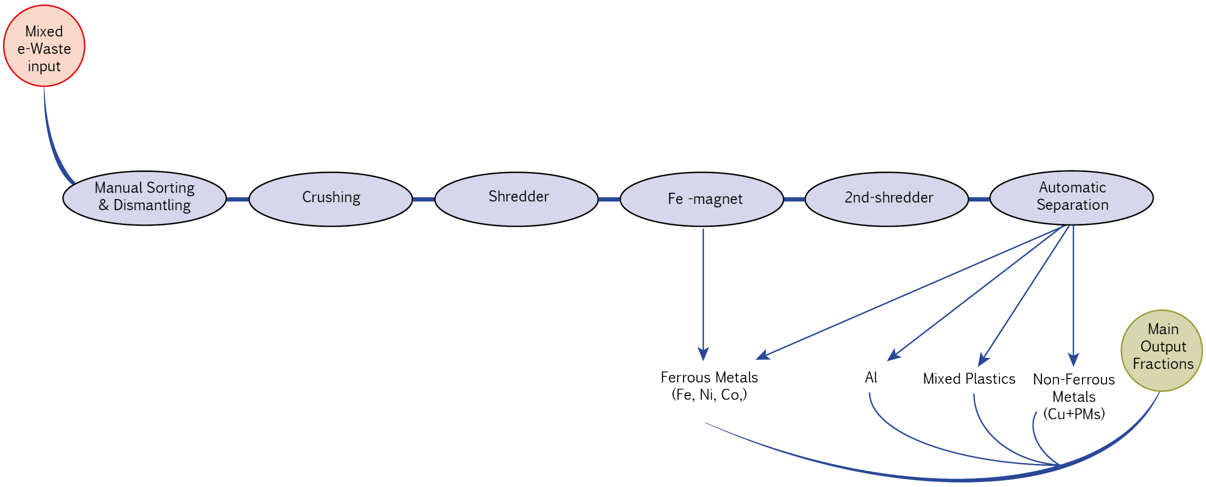

Figure 16: '*Pre-processing Steps at DCR-Environment'*.

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[43] E.g. include: mercury (Hg), beryllium (Be), lead (Pb), cadmium (Cd), arsenic (As), antimony (Sb) etc. and halogens such as bromine (Br), fluorine (F) and chlorine (Cl) (Hagelüken & Corti, 2010: 210). The RoHS Directive (2011/65/EU) has ensured that Pb is more or less phased out of e.g. solders. Some of the metals contained in the batteries are recovered in separate battery recycling processes.

[44] The actual processing mechanical/automation belt, were not allowed to be photographed and the observation was relatively fleeting. The overall steps have later been confirmed by Rasmussen at DCR-environment.

The manual steps: include dismantling and sorting. Many different components (e.g. PCBs, wires, cables, power supplies) are first liberated with normal hand-tools and sorted in to different containers. Hazardous components are found and sorted out[45].

The mechanical steps: A batch is put on a conveyer belt through first a crusher and next the main shredder which granulates to a diameter of approx. 8 mm. Then, a Fe-magnet sorts the large ferrous parts out before the batch goes through a second shredder, granulating these further into semi-fine pieces with a diameter of approx. 2,5 mm (Chancerel, P., et al. 2009: 12). An automatic eddy-current[46] separator did the last step, were the granulated scraps are now divided in to an 'Aluminium Fraction', 'Mixed Plastics Fraction' (with low non-Fe-metal content), a 'Mixed Non-Fe-Metals fraction' (with low plastic content), and leftover Ferrous Metal parts are separated over into the main Fe-fraction. The four end products can then be shipped out on a waste notification to a smelter or a refinery somewhere in Europe. The high value fractions such as the easily accessible PCBs from desktop computers, which were sorted in the manual step, can either be shipped out separately or run through a closed mechanical granulation.

As with any other treatment process, losses occur. The general manual dismantling is crucial for separation of hazardous substances and liberation of metals that are soldered or otherwise fasten together. The main problem is found in the granulated e-scrap fractions where it is unavoidable that metals enter the wrong fractions and also fine metal dusts are created. Thus, this processing method can be seen as being imperfect. Explained very simply; *"after crushing and shredding the size and composition of the particles has a distributed nature"* (Meskers, et al., 2009: 530). This means that parts of Iron granules might be fully liberated and sorted out while some remain in a mixed composition. Therefore, the fraction of mixed particles will increase with the complexity of the e-scrap that is being treated (ibid.). This means that parts of the liberated particles (of several different elements) might end up in wrong material streams (wrong metallurgical routes). An example of this problem, as may be surmised from figure 16, is the case of Aluminium and Copper. A piece of Aluminium may stick together with a bit of Copper and so the Copper will go to the Aluminium fraction. Once this happens, the Copper will be lost. Another example could be the precious and special metals embedded in a PCB, which could end up in a Fe fraction (ibid). The loss is actually first really happening in the end processing, but is due to the entanglement of metal fractions that cannot be recovered together – this will be discussed further later. Besides this complexity, fine dusts are created in the shredding process, which counts as loss as well. The recovery grade in the pre-processing is therefore very much a matter of how much fine sorting and dismantling that can and is being done (ibid.). Figure 17 shows pictures from the DCR-environment:

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[45] Also see guide to the Guidance on Best Available Treatment Recovery and Recycling Techniques (BATRRT) and treatment of WEEE - latest revision by DEFRA (2006).

[46] Based on Eddy Current Physics, which function by using different magnetic fields to drag and push fractions in to different splitters (UNEP, 2013: 182)

Figure 17: *'Pictures from DCR-Environment Pre-Processing Plant'*. (A) Dismantling station, (B) collected mixed batteries, (C) collected PCBs from desktop computers (D) collected mixed capacitors, (E) scrap on conveyer belt, (F) granulated e-waste plastics and (G) shipping bags with different grade fractions. (Pictures by the Author)

There are practically six different routes where the e-waste is finally distributed, as pictured in figure 18: 'Iron, Aluminium, Copper, PMs, Plastics and Hazardous Materials'. The pre-processing result can generate main losses with elements entering the wrong end-fraction:

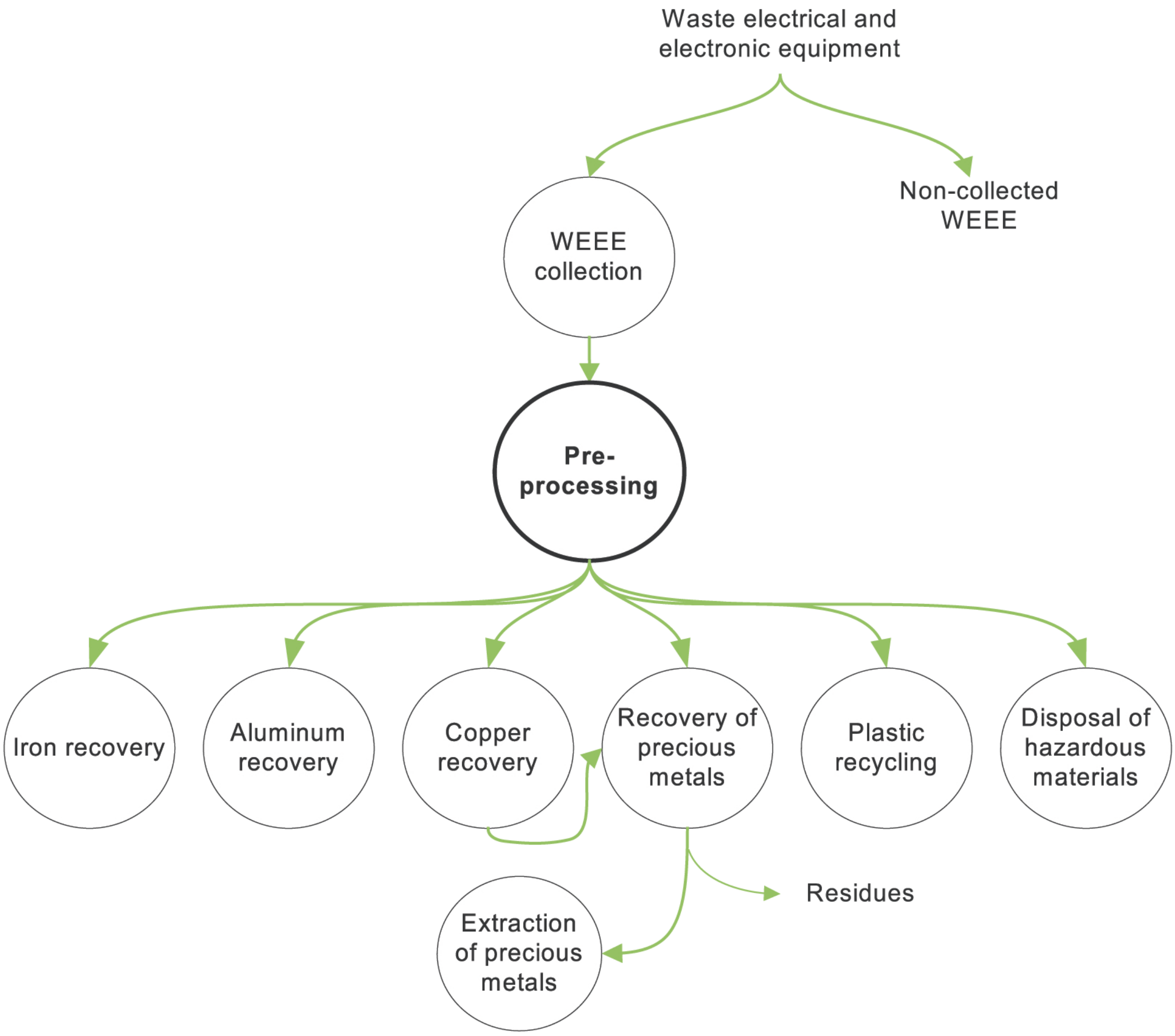
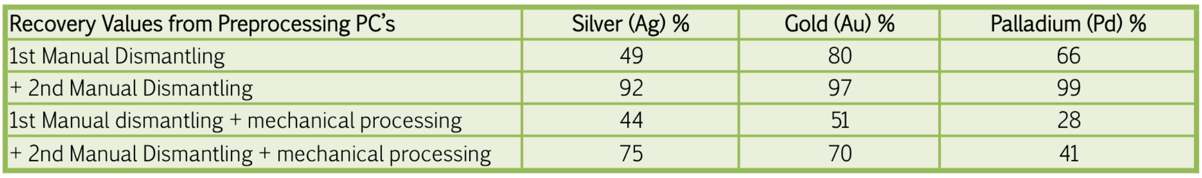


Figure 18: *'Resource Routes after Pre-Processing'*. Illustration re-printed, courtesy of Hagelüken & Corti, (2010).

So how large are the losses occurring in the pre-processing stage? Several studies indicate substantial amounts of the valuable metals end up in the wrong metallurgical routes. First it is important to recognize that the metals that make up the vast bulk of elements in electronics and ICT, e.g. Iron and Aluminium, are not valuable in economic terms, at least in the amounts that is embedded in these devices and appliances. Stated in another way, precious metals and copper are the metals that drive the economic incentive for recyclers to process the waste. These can therefore be seen as the 'paying metals'. For batteries however, it is mainly Copper which is the valuable metal (Hagelüken & Mesker, 2010: 188) (Hagelüken & Corti, 2010:9). The point is, loss in this stage heavily affects profitability of recycling for the end-processors. Therefore, the following studies focus solely on the recovery rate and losses of those metals.

The first study, by Chancerel and Rotter 2009, was done on 27 tonnes of ICT equipment (excluding screens and monitors) at a state of the art pre-processing plant in Europe. The mass-balance of this substance flow analysis showed that 11,5% of Silver, 25,6% of Gold, 60% of Copper was in the total recovered value fraction, after mechanical pre-processing. This means being placed in the correct fraction from where it can be recovered later on. Hereafter they found e.g. 40% of the Gold in the Ferrous fraction, and another 29% of the Gold in the plastic fraction. Meaning that, 74.4% of the Gold was ending in fractions where it was unlikely to be recovered in a smelting and refining process. This picture was evident for the other precious metals too (ibid. p. 8-12).

Manual dismantling can be expected to be most efficient when it comes to achieving higher recovery rates. The human eye and the skills it possesses have superior capabilities, though product designs make it difficult to take advantage of these fully (UNEP, 2013: 181). This was also shown in another study by Meskers et al. 2009, they evaluated the efficiency of a *second* manual dismantling done on PCs. Due to maybe a more homogeny sample mass of solely PCs, the recovery rates for precious metals were higher after only the normal first dismantling + mechanical separation (ibid. p. 538). The second manual dismantling was applied to drives, disk and power supplies, where PCBs were removed. Sparing further details, the achieved recovery values before shredding and granulation were substantially higher, as viewed in table 2:



Recovery Values from Preprocessing PC's	Silver (Ag) %	Gold (Au) %	Palladium (Pd) %
1st Manual Dismantling	49	80	66
+ 2nd Manual Dismantling	92	97	99
1st Manual dismantling + mechanical processing	44	51	28
+ 2nd Manual Dismantling + mechanical processing	75	70	41

Table 2: *'Results of Recovery Values'*. Data adopted from Meskers, et al. (2009: 537)

So, after a second dismantling they were able to achieve plus 90% "possible" recoveries, while the mechanical treatment in both scenarios generally added huge losses of precious metals to the equation. What is evident about these two studies is that the losses are great. To open the discussion mechanical processing is preliminary used to save costs in terms of time and labour in the pre-processing stage and to liberate the main metals like Iron and Aluminium plus the plastics. Complex products designs and the need for overall treatment of fast growing waste piles in the last decade, can maybe explain some of this development. So, after introduction of the WEEE directive that opened the possibility of mechanical processing, the game probably changed for the pre-processing recyclers.

Rasmussen generally expressed mixed feelings about the overall situation today. He explained that 10 years ago they where working only manually, in 3 shifts, day and night. Today they where having one normal work hour shift per day. The waste pile they were handling had grown fourfold from about 4000 to 16.000 t/y today (Rasmussen, appendix 5B, 2013: 10). The weight based WEEE-recycling system introduced with the directive in 2006, has then indirectly forced most pre-processing recyclers to invest in new machinery (to be competitive), because the e-waste piles where growing and they were still only earning from fees in service contracts. As discussed earlier in section 5.2, WEEE was viewed as a burden in the start. In light of this study, this focus has arguably changed gradually towards instead seeing some WEEE fractions as more valuable, which is why the technology and the approach that is used is still, perhaps, a bit old fashioned.

In this regard, Rasmussen explained that the fee they could take for their service, had been steadily falling since 1995 when the company started out. Despite the investments in mechanical processing, he saw labour hours, general logistics and administration to be some of the company's biggest costs today (ibid. min. 38-43).

Rasmussen also explained that they practically had to do the same manual liberation as they did 15 years ago, but as he recalls there was a lot more focus on easily recyclable products (easy to disassembly) from the OEMs. They made the components easy to click-on and off. He especially remembered a Fujitisu-Siemens PC line, where they in one-click could take out the HDD, the motherboard, the video card and so on – resulting in minimal labour time for every appliance or device. Rasmussen believed that today OEMs have no focus on this kind of easy disassembly what so ever, and everything is screwed, glued or enclosed. Mobile phones (smartphones) was his worst nightmare, because, they had to get at least the battery out, which most of the time are enclosed. The same was true for the case of the display, which they as their policy also took off for separate handling. They had also worked together with some OEMs on the processing of some prototype mobile phones, to develop security instructions, but had to reject those because they could not get the batteries out. On a general basis it was mostly the fact that they had to change screw heads all the time, because the components used several different heads in many different sizes (ibid. min. 6-8). Thus, basically some very simple problems in the manual dismantling step, where better designs for disassembly were number one on their wish list for the future.

Rasmussen also several times strongly stated that the lack of information around hazardous product components along with locating hazardous materials was very time consuming. In some situations they sought direct contact to the OEMs to get instructions and in some situations dealing with confusing or hazardous components they could get help from the CROs (El-retur), which sought contact on their behalf. In this regard, we discussed the opportunity for making simple information systems, in the likes of signs or colour codes on the components, that could enable them to locate the hazardous parts, which Rasmussen was in huge favour of (ibid. min. 20-24).

Summing up, it is clearly that use of inefficient liberation techniques and complex product designs is coursing valuable metals resources to be lost in the pre-processing stage. Incentives for both taking on finer manual dismantling and designing products for disassembly seem as an evident need to approaching better recycling and recovery. This relates to the principle of Design for Disassembly (DfD), which is described further in Appendix 2I.

5.4.2 End-processing

After pre-processing, or at least dismantling and separating out hazardous parts, the e-scrap can be shipped to an integrated smelter and refinery, for the actual end-recovery of metals. In this study, the subject is Umicore's Precious Metals Refining, which is a world leading company in metallurgical handling of e-waste[47].

Basically there are some main routes for these recovered materials. The ferrous metals fractions are shipped to steel plants, Aluminium-fractions are sent to Aluminium-refiners where it gets re-melted and so the precious metals fractions plus Lead, Zinc and Copper goes to an integrated non-ferrous smelter and refinery (Meskers, et al., 2009: 31). At the Umicore facility in Hoboken/Antwerp, Belgium they have a combined pyro- and hydro-metallurgical process that can retrieve and recover up to 17 different metals from e-scrap. The flow diagram is pictured in figure 19.

Umicore is able to recover all of the precious metals, the special metals (indium, selenium and tellurium) and the non-ferrous base metals Copper, Lead, Tin, Nickel, Antimony and Arsenic plus some Bismuth from the ferrous group of metals (Hagelüken & Corti, 2010: 6). In a new battery refining plant they handle the most common batteries in ICT, Li-ion and NiMH, where they are able to recover additional Copper, Cobalt, Nickel and some Rare Earth Elements (Umicore, 2013: a). Li-ion batteries, which are the most common ones in ICT (and the newer lithium-polymer), contain Iron, Nickel, Lithium-Cobalt-Oxide ($LiCoO_2$) Aluminium, Copper and Graphite (UNEP, 2013: 227f). Though these processing technologies are able to recover major amounts of precious and special metals, losses will inevitably occur, and can be found as off gas, in residues and sludge's. The Umicore processing has a highly efficient off-gas system, securing toxic emissions that should not be emitted to the air. Umicore has a high recovery-efficiency of above 95%, in their integrated smelting and refining processes (Hagelüken, 2012: 202).

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[47] Umicore (2013: b) has recently been ranked the number 1 sustainable corporation by corporate knights: see www.global100.org

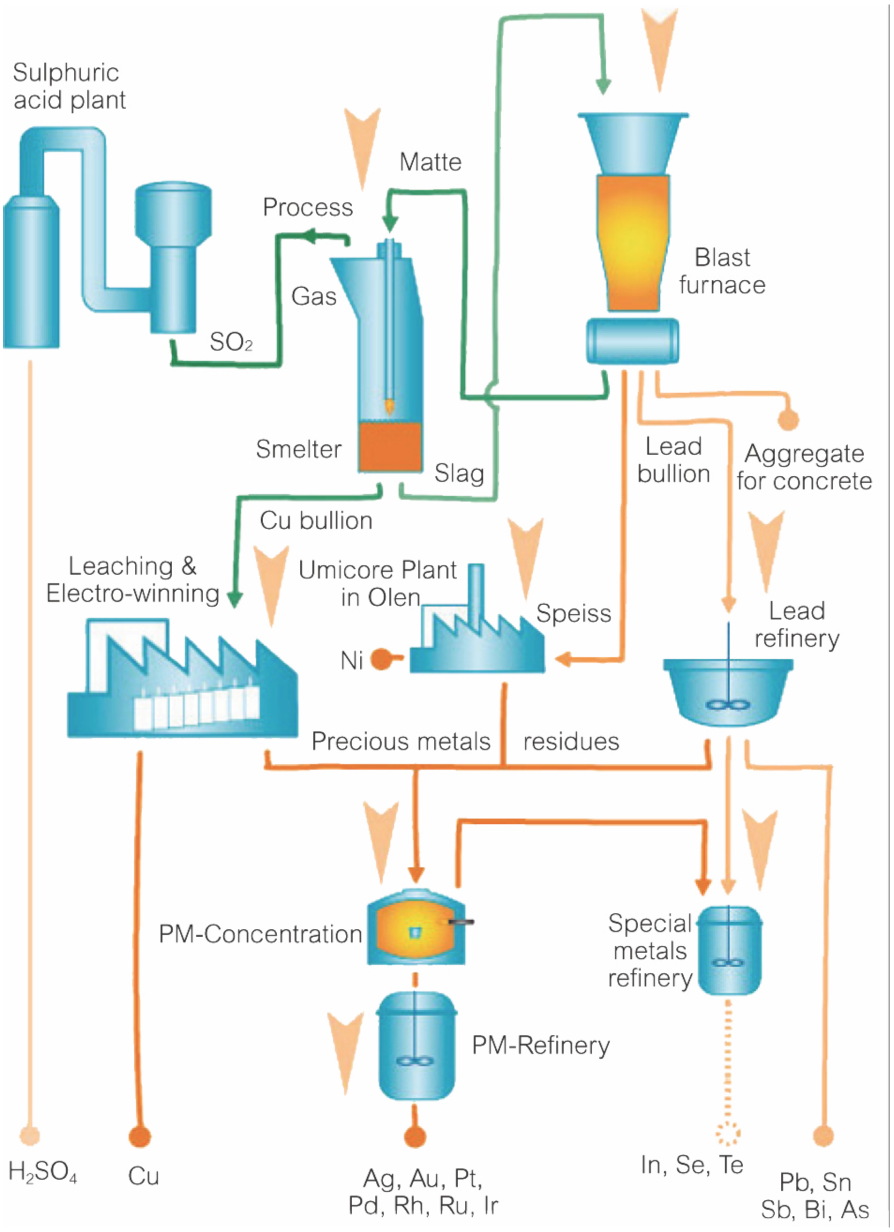

Figure 19: *'Flow-diagram of Umicore's integrated non-ferrous smelter and refinery'*. Illustration re-printed, courtesy of Hagelüken & Corti (2010: 6).

This basically means that 'if' high-valuable e-waste such as ICT is collected, dismantled and processed effectively, a large amount of the elements can be recovered. Besides securing recycled flows of valuable and vital metals, increasing the overall sustainability (recovery of metals), avoidance of many environmental and social costs can be addressed (appendix 3D). However, resource losses unavoidably also occur in end processing depending on how entangled the elements are and their physical characteristics relative to thermodynamics. See figure 20:

🟦 **Mainly Element Lost, not always compatible with Carrier Metal or Product** Detrimental to properties and cannot be economically recovered from e.g. slag unless e.g. iron is a collector and goes to further processing.

▨ **Dissolves mainly in Carrier Metal if Metallic (Mainly to Pyrometallurgy)** Valuable elements recovered from these or lost (metallic, speiss, compounds or alloy in EoL also determines destination as also the metallurgical conditions in reactor).

☐ **Compounds Mainly to Dust, Slime, Speiss, Slag (Mainly to Hydrometallurgy)** Collector of valuable minor elements as oxides/sulphates etc. and mainly recovered in appropriate metallurgical infrastructure if economic (EoL material and reactor conditions also affect this).

🟩 **Mainly to Benign Low Value Products** Low value but inevitable part of society and materials processing. A sink for metals and loss from system as oxides and other compounds. Comply with strict environmental legislation.

El **Mainly Recovered Element** Compatible with Carrier Metal as alloying Element or that can be recovered in subsequent Processing.

El **Mainly Element in Alloy or Compound in Oxidic Product, probably Lost** With possible functionality, not detrimental to Carrier Metal or product (if refractory metals as oxidic in EoL product then to slag / slag also intermediate product for cement etc.).

El **Mainly Element Lost, not always compatible with Carrier Metal or Product** Detrimental to properties and cannot be economically recovered from e.g. slag unless e.g. iron is a collector and goes to further processing.

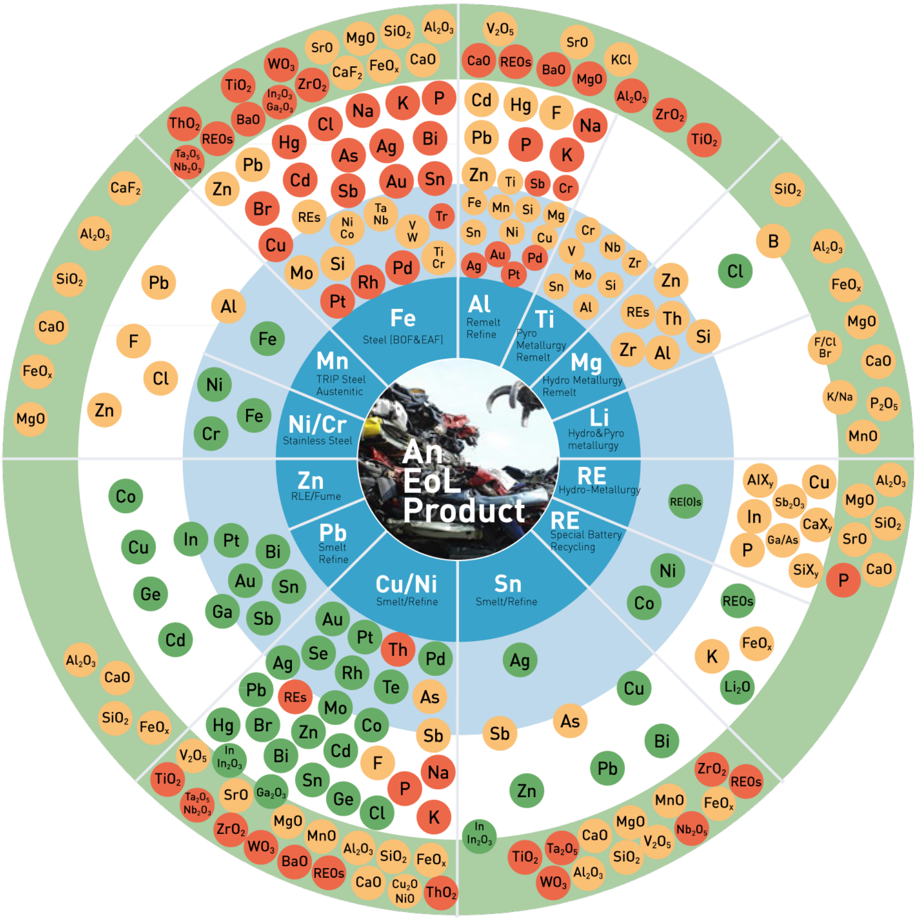

Figure 20: 'The Metal Wheel'. Illustration re-printed, courtesy of UNEP (2013: 62).

The 'Metal Wheel', explains how some metals end up in residues and sludge while others can be recovered. It is based primarily on metallurgy and from the base metal state (which can be seen as the carrier metal) on interlinked metallurgical technologies[48]. Reuters and van Schaik explain the general problem here:

> *"After mechanical separation, recovery in final treatments, such as metallurgical and thermal processing, it is limited at the microscopic level by the second law of thermodynamics. Thus, material separation and recovery in different phases (metal, matte, speiss, slag, flue dust, off-gas) are included in the models based on process thermodynamics and the chemical contents of and interactions among different elements/phases present in the recyclates obtained from dismantling and/or physical separation"* (Reuters & van Schaik, 2012: 341).

This means that physical and chemical properties of the elements (e.g. melting points, oxide stages) have a heavy influence when it comes to final recovery. Designing the products for recycling (and full recovery) is therefore very much a matter of looking at how different elements are entangled and coupled in chemical and physical groups, and additionally how distorted (imperfect) recyclates or waste fractions that are created from pre-processing. This position goes together with the Design for Environment and Sustainability (DfES) parameter, which target the strategic material compositions in products (Appendix 2I).

In the interview with Hagelüken he gave some clear examples of this complexity. For instance, "if a REE ends up in a ferrous cycle, there is no way to get it out and it's lost. It's about what technical wise and thermodynamically fit together". Hagelüken also explained: "even if you only have traces of e.g. selenium, tellurium, precious metals and copper, they fit well together and you can extract them. But if you have mixes of e.g. REEs and precious metals, or REEs and copper, or tantalum and copper, they don't fit and you loose one or the other" (Hagelüken, Appendix 5B: min. 9-11).

Hagelüken stated that higher collection rates was the most important problem to solve first, while also becoming way better at steering the metals in to the right recovery routes. In his point of view, this was the so-called *'low-hanging-fruits'* (ibid. min 19-21). The point is of course that this should be seen as the foundation of any recovery at all. Sometimes, talk of environmental friendly or sustainable design can maybe distort the focus from the first problem, which of course is that currently many small electronic devices are not getting an honest chance to be recovered at all. This point of view was also supported in another review of (mobile) smartphone's optimization potential for recycling (Öko-insitut, 2012: 41).

On the other hand, for the actual discussion on the design of products for recycling and recovery, Hagelüken was in overall favour of design for disassembly practices[49], in line with Rasmussen. However, in discussion

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[48] Castro, et al. (2005) has made a simulation comminution-liberation of recycling streams and the relationship with product design. Moreover, Castro, et al. (2004) published a thermodynamic approach to the compatibility of materials combinations for recycling.

about mobile phones, Hagelüken said that today they practically fed the obsolete devices directly in to the smelter, where they could recover most of the precious metals. Of course the battery again was to be removed, but the screen, either if made of glass, was made into a fine reducing material in the process. Hagelüken stated that the manual dismantling for these small devices was very costly, which is why it was not considered economical in the present situation, where the additional gains would be small (Hagelüken, Appendix 5B: min 1:45 – 5). Maybe this discussion was a bit confused in light of the present situation, where the obsolete mobile phones that actual get recycled today are mainly old ones (probably going 5,7 or 10 years back). It is thus logical to state that products of today, with large touch screens and many more chips packed on the logic board (as with smartphones), also creates a more and more complex starting point to recover from. The number of different elements in each product has also increased as a result of the industry's need for ever more exotic material properties (Schmidt, 2012: 2). These highly sophisticated devices at least have to be treated with the separation of battery and screens, even though they have not really reached the EoL stage yet (Öko-insitut, 2012: 41).

However, Hagelüken stated that; for the future, he believed that there were both limits and possibilities in disassembly, so what was crucial was having ways to easily remove the main components and avoid bad combinations. For instance, we also specifically talked about the aluminium casing that was used on Apple iPhones, which as he explained, was just oxidizing in the smelter and then simply getting lost – a clean example of a design feature which could be avoided by choice of material or making it easy to be separated out. For the larger devices and appliances such as computers, methods for separating every main component would be of great service towards the recycling and recovery of metals. As Rasmussen also favoured, this would include simple information or codes for locating hazardous parts (Hagelüken, Appendix 5B: min. 13-15).

Using the example of the popular iPhone from Apple Inc., it may be possible to take the discussion a step further. iFixit[50] stated in their first teardown of the latest iPhone 5 that they actually found it easier to repair, than its predecessor the iPhone 4 and 4s. What is evident about this is not so much the complete disassembly into tiny bits, but the time consumed to complete this process and access its main components.

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[49] Sometimes referred to as 'easy recycling', 'easy-disassembly', 'design for recycling' (DfR) or 'Design for the Environment'. A new guideline on 'design for dismantling' has been created by the French ENSAM institute of Chambery (2013: http://eco3e.eu/toolbox/design-for-dismantling/)

[50] iFixit is California based company making free self-repair manuals and video guides for people on all sorts of consumer electronics and ICT products – especially Apple products. In return, they earn on selling repair kits and spare parts online to people that want to e.g. fix a broken glass display themselves. This way, this kind of rebellious company, focuses on combatting the easy death of valuable ICT products and pre-obsolescence, against the growing amount of e-waste that is created (2013: www.ifixit.com)

Figure 21: *'Teardown of Apple iPhone 5'.* Picture reprinted, courtesy of iFixit (2013) (CC)

As iFixit explains; they used approx. 38 steps to isolate the display assembly on the iPhone 4 and 4 S, where they could do it in maybe 5-6 steps now with the iPhone 5. The same goes for the battery, which was located underneath. The display came right off, where before it was entangled with all the other parts. They assume they could use 5-10 min. now to disassemble the phone in its new version compared to around 45 min. before. This is still a large amount of time and as they also mention, Apple continues to screw everything together with their own kind of screw heads, 'the so-called pentalope screws', plus normal phillips screws (iFixit, 2012). In a recycling situation the gentle handling of the display and mini parts is not important, but in a situation of possible resale as '*reuse'* or *'refurbished',* it is.

In light of this, it is striking how proper product design is ignored in the industry, which seemingly do not fully acknowledge the European legislation. For instance, in the EU Battery Directive, it is stated in Article 11, that: "*Member States shall ensure that manufacturers design appliances in such a way that waste batteries and accumulators can be readily removed*" (Directive 2006/66/EC). Such an order is clearly up for discussion when it comes to present product designs and easy disassembly (e.g. with these mobile phones), because if its possible to misunderstand the term *readily removed*, it is probably not clear enough and such legislation must be strengthened and specified in the future.

In the conversation about designs for disassembly and the future recycling situation, Hagelüken talked about what he called the *smash-up* process, where some OEMs had previously designed and developed (at least prototypes) of devices that could be dismantled simply by force – e.g. smashing them hard to the floor. In such a situation, it would be easy to imagine that manual work could consist of just handpicking the different and tiny parts from a conveyer belt, where this kind of sorting could increase the metal yields by directing the bits and parts in to right metallurgical routes, while saving labour costs at the same time (Hagelüken, Appendix 5B: min. 15-16).

This also came up in the interview with Johnny Bøwig from DPA-system. He relayed a very interesting story: when the WEEE Directive was first implemented, he saw that the OEMs actual had taken every word into account, also the ones about easy disassembly and new product designs. He particular remembered a prototype of a Nokia phone, that when you smashed it, it was designed to break into several carefully selected pieces, exactly for these reasons. The problem came after, when they soon found out, that the recyclers (at least back then), wouldn't change the normal processing methods or pay extra for these special features (Bøwig, Appendix 5B: min. 35-36) though for efficient recycling and recovery of metals, this is exactly the kind of approach that is technologically needed.

The ideal for the future is clearly a system that connects the separated e-scrap fractions with the so-called carrier metals (base metals) directing these in to the right metallurgical smelting and refining processes (UNEP, 2013: 142). What can be discussed is the level of technological advancement that is needed in parallel, where exiting smelting and refining technologies today are not capable of recovering every element from the residues, but significant amounts. For these technologies to evolve and be developed, a supportive system with more focus and information on the actual product in hand and its internal components could lead to such, along a more sustainable path. It thus important that new initiatives can create the right conditions for extensive secondary raw material recovery by leading systemic change for technological innovation in easy recyclable designs for dedicated metal routes and material fractions.

5.5 Interim Conclusions

In the search for sustainability gaps, it is easily concluded that metals are used on various levels, some being structural materials and some being technological enabling ingredients. Together with problematic product designs it makes ICT products complex and thereby hard to recover elements from in the present. Systems flaws are manifold, but rely on the same paradigmatic foundation, in which waste is not yet fully seen as a resource by at least some stakeholders that take advantage and control these metal resources in the first place. The losses of resources and value in the post-commercialisation product life cycle can now be expressed by figure 22:

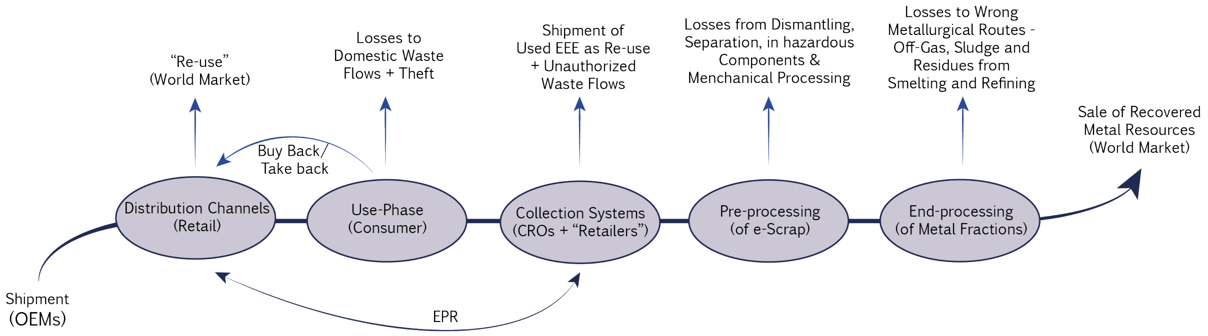

Figure 22: *Losses From Distribution to End-Processing'*. While the losses in the first tree stages were defined in section 5.2, it is now possible to view the whole post-commercialisation product life cycle as a range of individual stages that all seem to contribute to the final loss of resources and thereby value. The more technical and technological nature of e-waste processing result in challenges to resource transfers, since problematic product designs and systemic conditions force inefficient waste treatment processes. The e-waste might be treated to meet minimum environmental standards, but heavy losses occur since a more product-centric approach is hard for recyclers to use in the present. The disassembly into finer grade materials or component fractions is limited since only the absolute necessary steps are taken, resulting in irreversible losses in the end-processing stage. A confined conclusion is thus that insufficient collection limits the material input for recycling, plus the e-waste that do get treated is complicated by several interim technical losses in the processing stages.

5.6 Definition of Sustainability Goals

Continuing the theoretical and system analysis assembled in the vision (chapter 4), sustainability goals are to be defined from the three main objectives; *information transfer*, *resource and value transfers* and *technological innovation* to and from the post-commercialisation product life cycle. This means that sustainability gaps found in this chapter will be arranged under this formation as *goals to meet*.

The product-centric approach (UNEP, 2013: 2f) and focus of product flows in the post-commercialisation life cycle is the key to obtaining circular and sustainable flows of metal resources. What is evident behind the analytical findings in this chapter is that, not only is there need for a focus on products, but components and content of such as well. This should also enable more systematic and structured recovery practices, where higher yields can be recovered and value can be preserved. The goals are confined to 10 main objectives, which new initiatives should meet.

Information is found to be cut-off in more than one of the post-commercialisation stages, why it is found impossible to get full control of the resources after it has entered the use phase. In this present situation, an inefficient weight and volume-based system is the only option as it is now. As an example: New initiatives should gather information about quantity, components and the content in products, enabling stakeholders to seek more efficient and steadily improvements in metal resource flows thus increasing the opportunities for strategic and structured recycling and recovery operations. Therefore, new initiatives must:

Enable retailers and CROs to engage and participate in optimizing collections system, so information is shared and transparency is created throughout the post-commercialisation life cycle without being already lost after the purchase of the product has taken place.
Enable OEMs and their affiliated companies to re-establish a closer link with the collection system, ensuring strategic information transfer to the EoL phase.
Ensure that recyclers in both the pre- and end processing stages benefit from closer cooperation and information transfer with OEMs or their affiliated companies.
Ensure easy and possible cheap component oriented information for recyclers, such as colour codes or universal signs about hazardous parts and resource content.

Resources and Value is lost due to ineffective liberation methods, where the elements are entangled and embedded in complex products and components, which is why new initiatives simply must support a more product and component centred approach. Efficient and transparent collection systems are the heart of any recycling and recovery at all, which alludes to why reuse markets overseas are effectively in shadow and cannot ensure recovery of the resources. Additionally the resources are lost in the EoL-phase and treatment practices due to a sole focus on weight and volume based handling of the e-waste. Instead, a combination of a more in-depth resource focus in the mixed stream of waste products could increase the valuable recovery of the fixed metal resources, putting the product and its components in the centre. Ineffective combinations of entangled elements create thermodynamic barriers for obtaining the full resource and value recovery in the final EoL phase, and must be avoided in the future. Seeing metal resources as the economic and physical foundation for making business in the first place should thus reflect a changed mind-set about the elements needed and used for making ICT products. Additionally, consumers attach personal values to their ICT products, which needs to be further addressed for pursuing a more manageable and steady waste flow and why new initiatives must:

Ensure, that the products 'personal value' to consumers is taken in to account, even after their initial use of the device, establishing the possibility of more controllable, strategically managed, transparent and steady waste flows.
Ensure that the shipment of collected devices as 're-use' to markets overseas will be seen as less of an option, despite confusion of costs and benefits to recipient countries and their citizens, since this has uncontrollable consequences. Establishing a foundation for end-collection and thus a closed cycle.
Ensure metal resources can be kept in the value chain, transfering from recycling and recovery to product manufacturing; creating more efficient and beneficial resource flows. As a result, stakeholders in the value chain would rely on less dynamic resource costs, thus finally more viable commodity prices.
Ensure the creation of strategic recycling and resource recovery operations, where OEMs and their CRO representative can help to guide waste flows into the right metallurgical routes and recyclers can specialize and optimize processes from more homogenous waste fractions.

Technological Innovation has to be nourished as a result of fulfilling the above-mentioned goals, enabling the possibility for recovering higher metal yields of especially precious and special metals in the future. Combined, eco-innovative design principles and technological opportunities examined in (Appendix 2A), it is found that DfD and DfES is foremost needed for desirable change to take place. Therefore, the goals must include the following:

Ensure *Design for Environment & Sustainability* (DfES). Aiming to reduce the complex mix and number of elements in ICT products, to meet the metalurgical recovery challenge. Create an opening to future design possibilities of e.g. biodegradable compounds and soluble substrates, as ways to create ever more fine metal fractions.
Ensure *Design for Disassembly* (DfD). Ensuring easy component/resource liberation and a way to meet more efficient recycling and recovery operations.

6. Designing Scenarios – New Initiatives for Desirable Change

This chapter circles around developing and designing scenarios for the initiatives that were selected for this study (cf. the problem scope in section 1.4), including: *Deposit- & refund systems (DRS) and end-of-life management (EoLM)*. In correlation with the methodological approach, this part of the analysis does not seek to evaluate or define the final statements around these initiatives, but instead wishes to qualify and design these as an act of dimension. The overall visionary objectives of: securing information transfer, resource and value transfers and initiate technological innovation, show as guiding rulers for the analytical process in this chapter. This means, the further evaluation of these initiatives against the sustainability goals that were finally defined in the previously chapter thus take place in chapter 7.

According to J.B Robinson there is no distinct and prescribed method for taken on the scenario analysis, thus establishing a consistent approach must be defined instead. This includes a choice between a more quantitative versus qualitative approach and the possibility of using or not using a formal model (Robinson, J.B., 1990: 833). Apart from e.g. a technological feasibility or fully economic scope, this study is focused on elaborating new final systemic design features. Therefore, it is sought to define and elaborate upon central *Features of each initiative*, then seek inspiration in cases and *experiences from similar or past initiatives* and finally discuss and *develop design features* of each one. This procedure correlates to a more overall qualitative end-result, where quantitate data instead has been applied to elaborate, nuance and discuss different subjects throughout the analysis.

DRS and EoLM are of this study viewed together as strategic opportunities with the possibility to meet a circular and sustainable system approach, thus not necessarily separated from each other. Their interdependent nature is most clear when it comes to EoLM, since no obsolete products can be *managed* if the information, resource and value flow to management operations are not established by other means. Likewise EoLM will be mandatory to fulfil closed loops of physical products by a collection system like DRS. As delineated in chapter 2, the study will focus solely on developing system design around the case of mobile phones, and why these devices have shown to be a perfect example of an ICT product where solutions are very needed.

6.1 Deposit & Refund Systems

A DRS is usually arranged as a national system, where a ‘fee’ is placed on a product at the time of purchase (deposit) and so the users of the product reclaim this fee, when the product is returned at an official collection site (refund) (DØR, 2013: 282). Such as system on electronics, here focused on mobile phones, are greatly believed to be able to reduce transaction costs facilitated by the advancement in ICT and also be preferable to advanced producer led take-back schemes or advanced disposal fees (Milovantseva & Saphores, 2013: 15). It is in effect a simple economic instrument, which enables decision makers to put a value-based incentive in the hands of the person who has control of the product in the use phase. Apart from users normal relationship with things, where these lose the immediate value once they become obsolete in the eye of user, the product stays valuable until it is returned correctly (DØR, 2013: 282). This simple feature is not to be underestimated. Put in another way, many things in everyday life like plastic bags, cardboard cups or newspapers do not retain value after they lose their initial use value when its *"empty of groceries", "the coffee has been drunk"* or *"the news has been read"*. This highlights that idea that when there is a need to make people act in a certain way - like returning their used or broken mobile phone to a collection site - an extra economic incentive might show to be a clever tool.

- In the situation where the mobile phone is still functionally working, but the possessor find it obsolete for his or her use, it would create an extra incentive to return it for recycling more quickly, after the initial use phase, instead of e.g. storing it at home. Securing more steady disposal rates and possible abatement of wrong disposal in the end.

- In the situation where the mobile phone is actually broken, the feeling of invaluableness would not be present any longer, and the chance for people to return it for recycling, also for second hand users, would become much larger. This creates the main opportunity for efficient collection hence properly managed recycling and recovery operations.

DRS can be seen as method to increase collection and recycling of obsolete devices (both used and fully broken), but not as a direct incentive to increase eco-innovative design features alone (like DfD and DfES). However, combined with the right amount of information transfer, a direct opportunity for OEMs to re-gain control with the waste fraction (through the CROs) could perhaps lead to eco-innovative incentives indirectly, as a result of such a system in the future. This can maybe also be furthered with the right amount of supportive regulation.

A national based system would not do much for increasing OEMs eco-innovative design efforts, since they manufacture products to a world market, in why a DRS across Europe seem the best opportunity to create such indirect incentives (cf. section 5.2) (DØR, 2013: 298). However, a national 'success' example might be a good pilot for others to follow and at the same time establishing a needed foundation for collection – hence OEMs might then see eco-innovative design efforts as a real opportunity. This systemic nature and infrastructure of a DRS can thus be seen as a preconditioning societal integration for any future sustainable production and consumption behaviour (Power & Mont, 2010: 13).

The direct success criteria of a DRS constitutes around making an effective monetary incentive for correct collection and abatement of illegal disposal (DØR, 2013: 282). However, it could be discussed how to make the target group (consumers) subscribe to the idea, since a supportive social norm must be believed to strengthen the systems ability to combat the problem of wrong disposal. The Danish Economic Council here states that e.g. information campaigns and easy access to collection points must precede and support any regulation (DØR, 2013: 283).

According to the Danish Economic Council the price of the deposit should be given by the marginal environmental costs of illegal disposal e.g. from disposal to domestic waste channels. This creates the right incentive to correct disposal (DØR, 2013: 282) – this is also sometimes termed the socio-economic costs.

However, this simple notion should be reviewed since we found that people apply a ‘personal value’ to their obsolete mobile phones (cf. section 5.2). Alternatively, it should then be discussed how to find an acceptable fee to pay up front (the deposit), which they will be able to reclaim later on. This fee somehow has to be exactly enough for people to accept, without e.g. pushing consumers to seek discounts on foreign markets[51], and at the same time, enough to actually motivate consumers to return the device in the end. Rational economics implies that no matter whether or not consumers will be able to reclaim the fee in the end, they will always rather have the money in hand today instead of tomorrow. This is the reason why an acceptable versus effective deposit price could be seen crucial for both its support and creation of a good DRS.

Summarized conclusions for this section:

- DRS create a monetary incentive to return obsolete products no matter where they travel in society and thus while they stay in ‘use’.
- A single national DRS would not be able create incentives for eco-innovative designs, but if general introduced on European markets there is a fair chance it could have indirect effects on OEMs and create a foundation for a more sustainable production and consumption system.
- The size of the deposit could be determined by the environmental costs to society, but should also be evaluated against the personal value attached to the product.
- Public information and collection campaigns should be used prior to regulation.

6.1.1 Experiences and Perspectives on Deposit & Refund Systems

At present there are no general experiences with fully implemented DRS on mobile phones. However, the before mentioned idea of establishing information and collection campaign prior to regulation can be expressed by a couple of examples of take-back arrangements. The state of California (US) have had the most relative success in recent years, by implementing the “Cell Phone Recycling Act of 2004”, which puts a official ban on disposal of mobile phones to solid waste and features an order for retailers to establish take-back systems. The regulation is information and opportunity driven: retailers have to provide, inform and encourage the customers to use their take-back arrangement when buying a phone. The act came in to force in 2006, and has lead to a collection rate of roughly 21 % in 2010 of phones sold in California (DTSC, Government of California, 2010). Though the estimate is very vague[52] the act’s campaigning nature has still led to increased collection and recycling rates, which is double or triple that of the estimated European low collection rates (5-10% cf. section 5.1.1). Additionally, the Australian Mobile Telecommunications Association’s recycling program called ‘Mobile Musters’, established in 1998 by the main private stakeholders in the industry, were able to collect

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[51] E.g. on holidays, travels and online web stores.

[52] California law can’t require mobile phone collectors to report collected numbers, nor does it require manufacturers to report cell phone sales data. Therefore the measure is based on general US sales data provided by IDC versus estimated numbers of phones take-back in retailers throughout the state.

10,3% of obsolete phones in 2011/2012 compared to yearly sales, through only information and established collection opportunities (AMTA, March 2013: 3). This collection rate is slightly less than the example from California (with approx. 21%), but provide an additional empirical example on what can be achieved by providing rightful information and establishing collection infrastructure. These combinations of retailer cooperation, maybe law enforcement and public information, should therefore be seen as a minimum requirement prior to implementing DRS, so the basic system comes in place and citizens become aware of it at the same time.

An example of a fully functional DRS is found around lead-acid batteries, and according to Walls (2011), 44 states in the US have general systems implemented, where retailers voluntarily have implemented a 10 USD deposit on lead-acid batteries, which can be refunded if the customer returns an old one within 30-45 days. What is important here is that this private company driven model has led to 97% collection rates, so batteries can be recycled for lead, other metals and plastics (Walls, M, 2011: 3). Here, a relatively low fee makes a great deal of impact.

Most significantly are the DRS's that are widely and successfully implemented around beverage containers. This includes containers like Aluminium cans, PET and glass bottles. In the Nordic/Northern European countries (including; Denmark, Finland, Island, Norway, Sweden + Germany and Estonia), this type of DRS is fully in national systems. In Scandinavia and Estonia, these systems are founded on national legislation and controlled by government initiated non-profit recycling companies that is given the exclusive right and include implicated private stakeholders in different combinations – e.g. as shareholders, board members and so forth. Opposite, in Germany DRS is founded and controlled solely by the trade and industry organisations.

The deposit is generally fixed around small variations in the fees, differentiated on the size or type of container. The deposit fees in the different countries range from approx. 0,10-0,50 EUR per container (Rehnberg, J., 2010: 12-33). In Denmark it is mandatory by law for producers and importers of beverages to submit to Dansk Retursystem A/S (the exclusive recycling company). Providers (e.g. grocery stores, hotels and restaurants) that sell beverage can voluntarily submit to the system as a collection site and Dansk Retursystem A/S will then provide the logistics and regular pick-ups free of charge (DRS A/S, 2013: a). Most do so and today practically every grocery store has an automatic refund machine in place – approx. 3000 machines in 2700 stores, where approx. 6000 stores accept refundable packages in total (DRS A/S, June 2012). It can be assumed that grocery stores and supermarkets chains can be expected to generate significant additional revenues from customers that take their bottles and cans to their store and shop at the same time. Getting the customer inside the store must be believed to be important here, where a good and functional refund machine possibly makes a difference for the final turnover.

The collection rates are usually very high around these DRS for beverage containers, where 89% of one-way packaging was collected in Denmark 2010. In 2011, 104% of refillable packaging was collected, meaning more than what was sold in the year and is due to a general phase out of this type of packaging (DRS A/S, 2013: b).

This experience with a DRS around beverage containers show that such a system is very effective at securing high collection rates. Opposite to e.g. environmental taxes on products, a product-fixed deposit secures collection even if the device is picked up somewhere else in the society (DØR, 2013: 283f) – in the case of mobile phones, thus after it shifts hands on e.g. the second hand market. This secures the picture of possible making a relatively simple system, which enables very efficient recycling flows of resources.

However, the main differences between the objects of beverage containers and mobile phones, are that the use cycles are much quicker for beverages, the system is by default much more locally or regionally founded (for production and distribution), processing is obviously more simple and finally consumers have an almost converse relationship with the object in hand (low price everyday commodity versus high price and social status commodity). These are all issues that must be taken into account. The good thing about this case experience, and looking further towards DRS opportunities for mobile phones, is that consumers in Denmark (and other northern European countries) are fully aware of this kind of system (people are accustomed to it), thus an integrated part of the culture. Therefore, possibly securing quick adoption for other DRS systems.

In this light, the Danish social-liberal party[53] made the suggestion to actual introduce DRS on mobile phones in may 2012, with a deposit size of 50 DKK (6-7 EUR). According to their proposal, the DRS should be based on the same well-known idea of beverage containers, with; automatic machines in grocery stores around the country and should also include objects such as batteries and mp3-players (Radikale, 2012: a). Despite this political will and opening for debate, the industry and business societies didn't respond in a positive manner towards this proposal of introducing DRS on small electronic devices. In a good sense, they believed that the proposal was too thin and wasn't based on the reality in the market and present WEEE-system. The main points of critique', which were mentioned, included:

- A reference to a Danish EPA study, which investigated domestic waste fractions, where only small amounts of WEEE was found, so most obsolete mobile phones were still believed to be stored at home (yet to be recycled).
- That this type of system would be very costly as pertaining to the introduction of automatic refund machines in all of the country's grocery stores, not worth the benefit or effort.
- That recovery technologies for metals like REE are yet to be developed, and therefore could not be expected to be recycled from these waste fractions.
- That such a system would distort the competiveness against other foreign markets.
  (BFE, 2012: 4)

These are reasonable concerns to be assessed. However, both the political proposal and critique might seem a bit unsubtle and simplistic, why these points should be discussed further. In the matter of stored versus wasted

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[53] Det Radikale Venstre – www.radikale.dk - The party is part of the present Danish government coalition.

mobile phones to domestic waste streams, decision makers must look at the first real problem; that mobile phones are not found to be recycled in general (cf. section 5.1.1), highlighting that a way to create steady and controllable recycling streams is still evidently needed. Where the obsolete mobile phones actually go is still a mystery and so they might be scavenged for the so-called grey waste streams, given to charity and so forth.

The costs of investing capital in refund machines, is based on the assumption that this is somewhat the only way of making a functional refund system – with regards to both the proposal and the critique. With beverage containers the volume collected every year is very different from what could ever be expected on small electronics – with approx. 800m one-way packaging units in Denmark 2011 (DRS A/S, 2012: b). Around mobile phones, we look at the generation of somewhere around 2m unit/yr (BFE, 2013). This indicates that a simpler infrastructure could be more than enough for this type of volume – thus a possible DRS for mobile phones must be followed by proportional and cost-efficient collection infrastructure.

With regards to the present recovery technologies of metals, the analysis in section 5.4, more than indicates that higher collection rates and a systemic product approach is the most important precondition for recovering metals in the first place, and why both the recycling and recovery technologies which continuously will be developed (also for REE) plus investments, will only seize the day, in the presence of better and more efficient systemic conditions. Therefore, this critique simply cannot be justified.

The critique of losing competiveness is found the most reasonable argument against introducing a DRS. However the commercial value that can be generated from such a system is not encountered here. Additionally, this critique should rely on a much more thorough market analysis with significant evidence for major revenue losses to competing markets, in the presence of a deposit, where in relation to the reasoning in the previous section, must encounter the magnitude of the deposit fee that is being discussed. As an example: 50 DKK (or 6-7 EUR) would correspond to approx. 0,5-1,5% of current mobile phones sale prices[54]. Additionally it is important to mention that consumers will actually expect to be able to reclaim the refund in the end. Therefore, there is no evidence that people will perceive a deposit fee as a general loss in the purchase situation, nor the other way around. The only thing that is for sure is; by introducing a DRS, people would have to get accustomed to the ‘idea’ for some time, why the feeling of lost money can be expected to narrow out if people accept the system as good for society. Nevertheless, this critique point of lost competiveness is discussed further in the next section when we look into determining possible deposit size.

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[54] Based on present Danish retail prices from Pricerunner.com of approx. 3000-7500 DKK (400-1000 EUR) on popular mobile phones such as Apple iPhone 5, Samsung Galaxy S4, Sony Xperia Z, LG Optimus G, HTC one.

Summarized conclusions:

- A DRS have the possibility to secure very effective collection rates.
- Generate quantifiable information on commercialised versus collected obsolete products.
- A system on mobile phones would need a proportional and simplistic design, complimenting the scale that is actually targeted.
- The deposit size must be evaluated against lost competiveness to foreign markets

6.2 Opportunities for Deposit & Refund Systems on Mobile Phones

In correlation with the findings in the previously sections it is important to establish an idea of the general recognition of a DRS for mobile phones. This means, how consumers perceive such a system if it were to be implemented today. In the consumer survey, conducted for this thesis, the respondents were then simply asked if they found it as a 'good' or 'bad' idea. To give as truthful a picture of how people in general would immediately perceive DRS for mobile phones, they weren't presented with any information on environmental or social benefits of recycling phones; however, to give them the ability to respond as naturally as possible, a short explanation[55] of the features of DRS was given beforehand.

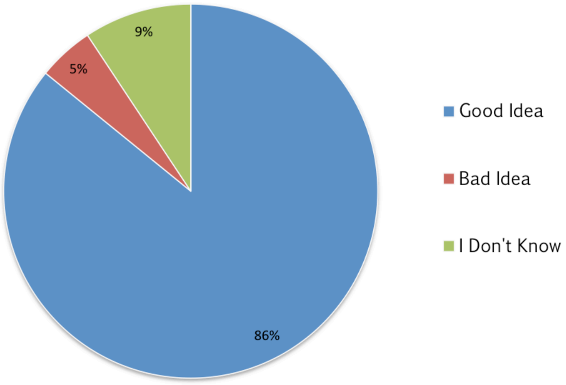

Figure 23: 'Perception of a DRS for Mobile Phones'. (Appendix 5A: Q9)

The 86% who thought of a DRS as a 'good idea' is a very clear statement that people would act positively in its favour, if it were to be introduced. The relative younger crowd, who was surveyed here, have also largely grown up with a DRS on beverage containers, which favour the recognition of the valuableness of such a system. The Danish Society for Natural Conservation[56] has also made a similar survey in 2012, carried out by the analytical bureau *TNS Gallup* with 1240 respondents, with a very similar result in its favour. Due to the capacity and survey method of TNS Gallup, this is way more representative for the Danish population as a whole, with differentiation on ages, geographical regions, political conviction, with an almost equal representation of

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[55] Information incl. that the idea was to increase collection and recycling rate on mobile phones, that a fee would be paid when the phone was purchased and could be reclaimed at different collection sites, and that it would follow the phone so it was possible to resell the phone to third party and keep the phone for a desired amount of time.

[56] Danmarks Naturfredningsforening – www.dn.dk

gender. However the question of a DRS on mobile phones was given on the background of a quick environmental statement about the negative loss of electronics to domestic waste streams. Hereafter, they asked how people agreed with the suggestion of introducing a DRS on mobile phones. In total 74% found it as a good or very good idea (TNS Gallup, 2012: 6). Finally, The Danish Society for Engineers also made a similar survey in June this year, with 1015 respondents. Here the result was 62% in absolute favour of such a system (IDA, 2013: 2).

Despite, the slightly different approaches in the question methods, it is still a very clear statement that the majority of people would favour such a system. The slightly more negative approach from people in these national based surveys might come from the fact that they were not given a full explanation of DRS characteristics, or, it might have to do with this author's survey being narrower and less representative for the population as a whole. The overall positive approach is important in addressing the problem of success in a time horizon. If mobile phones can be expected to have an initial use phase of approx. 2 years (cf. section 5.1.1) and additionally a couple of years in extended use as reused by someone, the temporal perspective of success, can be expected to be at least as long. DRS for mobile phones would therefore need a much longer run-in period, than for other products with a much quicker use phase and life cycles. This means, a DRS on mobile phones cannot be expected to reach full system capacity before 3-5 years in operation. A positive recognition of such a system must then be expected to be valuable, since it would need time to be fully integrated in society.

In this regard, a feasibility study on the same possibility of introducing a DRS on mobile phones in Norway has recently been conducted. The overall study focus was broadened, including small-WEEE and light sources (Dag-Friss Baastad, 2012: 5). Here they suggested addressing the issue of the so-called 'historical' or stored phones[57]. They suggested that an introduction of such a system should then be conducted in two phases. The first including a wide scale national campaign, where different stakeholders OEMs, MNOs and retailers in general, should be engaged[58]. The idea was to use the opportunity to secure collection of historical phones and at the same time culturally and effectively adopt the idea broadly in society. If people were to hand-in their old mobile phone handset, they also thought there was good reason for collecting other types of historical products at the same time – e.g. old mp3 players, cameras and so forth (ibid. 2012: 18-19).

This potential win-win situation by conducting the system integration in two phases is hard to disagree with – thus should be followed. However, it may be problematic to introduce the system for a larger variety of products, not because people would have a difficult time bringing different obsolete products to the collection point while they are already on their way, but because it might distort the message in the campaign. For example: An obsolete camera cannot be expected to have the same personal value to people as obsolete phones, and why a campaign that seeks people's goodwill to return various old devices, might end up having a blurry

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[57] In section 5.1.1 it was estimated that approx. 10m obsolete mobile phones could be found stored in Danish homes

[58] By given stakeholders e.g. 6 months to report if they wanted to participate.

picture, in the end, only getting a small amount of phones returned[59]. However, an investigation of the opportunity to expand a DRS in the future, to other small consumer electronics and other ICT products, might be more valuable once people become accustomed to the idea through mobile phones. The chance that people will bring other obsolete and small devices once they are already on the way to the collection point is probably large anyway, and additionally suggests that the initiators could choose to ensure the acceptance of selected variety of small electronic devices. Secondly, it could be discussed how to approach efficient collecting rates of historical phones, by maybe paying out a limited refund for the old devices based on the either their scrap value, or, the socio-economic costs - simply to encourage people.

Summing up the findings of this section, it is clear that a DRS have a generally positive public recognition that can show fruitful in the expected long run-in time of such a system. Outside this national context of Denmark, it is unsure how people would perceive such a system. One way of establishing a strong culture of correct collection is to address the issue of historical phones and use it in a start-up campaign, hence creating a foundation for long-term success. In other countries, and especially where no DRS's are in place today, it would thus seem necessary to proceed more carefully.

6.2.1 Resources & Value

The value embedded in phones can be expressed by two variables - the scrap value of the embedded metal resources and the personal value to people. While the scrap value is expressed in dynamic metal prices on the world market, it also has an underlying socio-economic value, which could be addressed as well.

The scrap value of a single phone that can generate monetary revenue can only be expressed by the immediate value of the actual recovered metals in the EoL phase, why metals that are not recovered today cannot be accounted for here. A relative conservative[60] socio-economic analysis including the scrap value of a mobile phone, were recently conducted by the consultant company NIRAS on behalf of the Danish EPA, which expressed a very secure positive outcome[61]. By a final division of the product value in to four variables, they

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[59] In a situation where people where encouraged to hand in everything from old light bulbs, to camera, phones and mp3 players, they might not see the underlying message. Focusing solely on mobile phones, which are regarded as having the greatest personal use value to people, might help to enforce the environmental valuableness of doing so, why people would be expected to need extra encouragement here with this device in particular.

[60] Only the monetary values of the most economical important elements are accounted for, which includes: Gold, Silver, Copper, Cobolt, Nickel and Lead. In state-of-the-art end processing it's possible to recover a larger variety of metals, why this intrinsic value only can become larger apart from this narrow focus. However it, a narrow focus is good for setting a realistic and minimum possible value creation.

[61] Uncertainty of the calculations is carefully outlined in the CBA study as a sensitivity analysis. This showed that even if no metal resources were recovered at all it would still have a positive socio-economic value to recycle mobile phones. Similar, the costs of disassembly the battery from the phone would have to be 20 times larger as well, before it would have a negative impact on the scenario. Finally, if the processing costs were doubled it would only have a minimal impact on the positive socio-economic value. The full sensitivity analysis can be found (The Danish EPA, 2013: 97-99 [b])

carefully concluded the socio-economic costs and benefits to be a positive 24,61 DKK (approx. 3,3 EUR) expressed as followed:

CBA of a Mobile Phone (109 g. per unit)	DKK	EUR
Processing Costs (Incl. transport, disassembly & sorting)	-1,9	-0,255
Energy Savings	1,08	0,145
Recovered Metal Resources	17,87	2,4
Saved Emissions to Air	7,55	1,01

Table 3: *'Socio-Economic Value of single Mobile Phone',* taken from The Danish EPA (2013: 97 [b]).

This result shows us that even if only the monetary value of the metal resources were accounted for, it would still have a positive value of approx. 16 DKK/2.1 EUR (processing costs subtracted), which could be obtained for the collection of one phone sent to recycling. The socio-economic benefits do not pay off directly to the possible associated DRS stakeholders, for instance CO_2e savings are a global benefit. What is not accounted for in the study was the additional turnover from the economic activities in EoL phase, which creates tax revenues benefiting society directly. In Europe, the processing variable would be cross-national, where these tax-revenues also would be. Increased collection would not only create benefits in the form of added tax revenues from the economic activity, but also result in the creation of new jobs in the waste-treatment sector. However, these added values are only mentioned here, but not accounted for further, since it is not intended to make a full CBA in this study.

Decision makers could choose to include an 'incentive' refund to people (Small refund for the old "historical phones"). Here it would be necessary to rely on the scrap metal resource value solely. However, it is important to encounter the possible fluctuations in metal prices, and why a safe value must be preferred to prevent a negative economic scenario, even though greater monetary value can be expected to result in a greater incentive for returning historical phones. As examples we can use 10 DKK as a safe scrap value. If then 10 DKK/1,35 EUR were refunded for every collected historical phone it will equal an obtained monetary scrap value of 37,5%, which is left from the approx. 16,00 DKK generated per phone. This means 6 DKK/0,80 EUR is the revenue per phone after a potential refund load is paid out, which could then be used to fund a national collection campaign.

In this sense it cannot be expected that every historical phone could be collected through a national campaign, but decision makers can address the criteria of success by evaluating the extent of it. A minimum possible collection rate could be set to somewhere between 10-20% of the assumed 10m historical phones over a year, in order with past experiences in other countries (cf. section 6.1). Knowing that there is a fairly good waste and recycling culture in Denmark and that there is a vast net of government run recycling stations around the country, it can be assumed that this would be closest to 20%. Therefore, a partnership between retailer and government stakeholders might the best option here, taken into consideration that people would be accustomed to using the normal recycling system. Thus, it is more likely that people would bring obsolete phones after getting exposed to the campaign, while they are already on their way with other types of waste. A majority of broken phones would naturally be handed in first, while still functional phones would come secondly, since people like to use them as backup and so forth.

Calculating from these numbers sets the budget for running first step of a DRS introduction to approx. 32m DKK/4.3m EUR in the first year, based on collecting 20% of the historical phones, or, approx. 2m handsets in total. And so, choosing to run the campaign with a small incentive refund on 10 DKK would decrease the budget to approx. 12m DKK/yr (see calculations in Appendix 4C).

6.2.2 Size of the Deposit

In section 6.1 it was determined that deposit size should equal the environmental costs of illegal disposal according to the Danish Economic Council. These costs could very well be expressed by the socio-economic benefits showed in the previously section. Therefore, setting the deposit size to approx. 25 DKK/3,3 EUR would show as good minimum foundation for a DRS system.

However, as previously examined it would be necessary to find a deposit fee equal to the personal value which people attach to their used phones, as of approaching full collection. This makes it a more difficult task to work around. The first issue is to settle a deposit fee that would make most people return the phone once it becomes obsolete – their *willingness to return*, determined by a given monetary value. At the same time their *willingness to accept* should be found, which can expresses the highest monetary value they would find reasonable to deposit. Thirdly, people should be given the opportunity to express what value they find *fair* as a deposit.

As part of the consumer survey for this study and in addition to people's general perception of the idea of DRS on mobile phones, they were asked to set the monetary value range of the deposit fee, in this very order (Appendix 5A: Q12-14). These three questions were based on a fixed rating system. The lowest values they could select were 10 DKK corresponding to the safe minimum for resource recovery and 25 DKK in order with the socio-economic benefits. The middle values corresponded to the price range of 50-200 NKK, as suggested in the Norwegian study (Dag-Friis Baastad, 2012: 31). The upper values topped 500 DKK, since anything above that is regarded as unacceptable in a commercial sense. This is also why respondents weren't given the opportunity to select random values on their own.

The result is found in Appendix 4B, and shows both visually and statistically that people favour even and solid values like 50, 100 and 200, why this could be used to select and determine an effective deposit size – hence, people seem to have generally a better perception of how much these values are worth to them, than a more random number like e.g. 175 DKK. An average were calculated from each value category and a mean value, determined by the number of entries in each of the 10 intervals, expresses where minimum 50% of respondents targeted a given value set above.

The average values are found to be 150 (Willingness-to-Return), 250 (Willingness-to-Accept) and 200 DKK (Fair). This constitutes to an overall average at: 200 DKK, which they on average also found most fair. Additionally, five values can be seen as interesting and is evaluated underneath:

- **50 DKK** is the absolute lowest option since 27% said they would return an obsolete phone, why any return target must be higher than the maximum 10-20% collection rate, which can be expected from public information or a campaign, though the acceptance is nearly perfect.
- **100 DKK** has a very high acceptance (93%) and a relatively okay return rate (59%). With the right amount of information, people would properly adapt quickly to this value size, but a significant amount of people don't regard this as enough to return their obsolete phone.
- **150 DKK** is the value with highest equality between return and acceptance, and why this could be seen as a good choice of deposit size. This is also the mean value of what responders regard as fair.
- **200 DKK** is the overall average and the return rate jumps quite a bit to 85%, which makes it very effective compared to the size of the deposit. The acceptance rating is still fairly good (66%), and with the right amount of information, this might be adopted more widely among people as being okay.
- **250 DKK** wasn't a choice in the survey, but is the absolute top on average, where at least 50% of the people would accept this deposit size. The extra gain in return can be found enough to justify this value, why 200 still looks like a better choice.

In a Danish context, 100 DKK can be favoured because it would both be relatively effective and easier to adopt among stakeholders in the private sector and very easy to adopt among consumers. However 200 DKK looks fairly more effective, but suffers from being conversely harder to adopt among stakeholders. What speak in the favour of choosing 200 DKK is that it is politically easier to adjust the value down in the future[62], that inflation would erode the power of the value over time and that the environmental benefits would be much greater (high collection rate).

Therefore, decision makers must either choose a deposit size as *easier to adopt among stakeholders* or as *more effective in the long run*. In the case of other countries, in a European setting, it could be seen as enough or maybe a more perfect choice to select 150 DKK, which is exactly in between and corresponds to approx. 20 EUR, which is also a good solid value[63].

In relation to the previous discussed idea of a using small incentive refund on 10 DKK, the picture unfortunately looks rather ineffective, since only 8% responded they would return for this amount. Therefore, decision makers must carefully consider this in the first step of a campaign, since even such a small refund would maybe erode the budget to build-up a formal DRS. Using the socio-economic value at approx. 25 DKK would also be inefficient, since only 10% found this enough to return obsolete phones. The conclusions is that a useful and

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[62] In the case of the Danish DRS on beverage containers price were adjusted down in both 2004 and 2011 (DØR, 2013: 288)

[63] However, additional research would be necessary to determine a good deposit in a foreign context.

thereby effective deposit size, must be between 4 and 8 times greater than the socio-economic value of correct disposal.

In section 6.1.1 it was examined how private stakeholders expressed concerns about losing competiveness against foreign markets at a deposit rate of 50 DKK. The concern could stem from the fact that such a ‘deposit’ would be publicly perceived as a tax, which would make consumers turn to foreign markets – for instance on travels, holidays and through online sale. In the case of online purchase from foreign-based web-stores the deposit would have to be put on top during the formal transaction. The same situation would be expected to be the case for national based web stores; hence it becomes a question of appropriate regulation. Nevertheless, the convenience of purchasing a mobile phone locally or from local retailers, also in case of easy warranty reclaims, must be believed to have some impact on people’s choice, rather than the opportunity of saving a given fee up front. However, if the fee is too great, and DRS for mobile phones are not broadly adopted in the rest of Europe, the issue must be considered to become more relevant.

If we additionally look into the official statistics Danish households spent an average of 1127 DKK on telephone devices[64] in 2007, while in 2010, they spent 4083 DKK (approx. 150 EUR in 2008 versus 550 EUR in 2010) (DST, FU5: nr. 8211). This equals an extensive 262% average increase in spending over three years[65]. The amount of mobile phones sold in Denmark were around 2m in 2007, while it had fallen to around 1.82m in 2010[66] (BFE, 2012: 27f)(DST: FOR411), which only makes a 9 % market decrease over these three years[67]. This means consumption has shown to be relatively unchanged in the period, while households have a significant increased spending on telephone devices. The main reason for the increased spending is that the mobile phone markets has changed quite a bit in recent years, where consumers now buy into the more expensive smartphones markets opposite to feature phones which is phased out. This has to do with the market introduction of long-term *‘repayment schemes’* of up to 2 years, which have let consumers increase their spending per device (see further elaboration on repayment schemes appendix 4A). The same period was also market by the economic crisis, which was expressed by a decrease in the general e-waste collection (DØR, 2013: 294). This means that the relatively small decrease in mobile phone sales between 2007 and 2010 might have to do with people holding on to old devices longer, due to maybe financial uncertainty, rather than necessarily reacting to increased sales prices.

The conclusion is that a deposit size, even in the range of 200 DKK, cannot largely be expected to change the consumption behaviour significantly. As discussed in section 1.1 and 5.1.1, mobile phones is largely seen as a

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[64] Statistics Denmark (DST, ‘FU5’). All households/Fixed Prices/Commodity nr. 8211”Also representing landline telephone equipment”, but these can’t be expected to have any significant share since they where largely getting phased out at this time (DST, 2013: 2).

[65] 4083/1127 DDK = 3,62 (-1) = 2,62 (X 100) = 262%

[66] Danish mobile phone sales were 1.92m in 2011 and estimated to reach 2m again in 2012 (BFE, 2012: 27)

[67] 1.820.000/2.000.000 = 0,91 (-1) = 0,09 (X 100) = 9%

necessity in modern society, why price changes thus seemingly have to be massive to keep consumers from buying new mobile phones.

6.2.3 Collection Points, Costs and Funding

If a DRS should be established collection points could be arranged around the existing recycling system. However, in the Norwegian study they adequately point out that the success of the DRS on beverage containers was fairly linked to convenience and thereby how extensive the net of collection points was, hence the availability to people (Dag-Friis Baastad, 2012: 13). This speaks in the favour of adding retail stores to the map. Only 15% responded in the consumer survey, that they hadn't returned their obsolete phone(s) because they either forgot it or had difficulty to get to the recycling stations (Appendix 5A: Q11). However, this can still be questioned, since the main reasons for storing the phones centred on keeping them as a backup. Additionally, the visibility of also having collection points at retail stores cannot be underestimated, which is why conversely most normal recycling stations aren't assumable exposed to people on a daily basis. Engaging the retailers will also more easily link information and campaign efforts to the stakeholders in the distribution channels, directly on the market. Retailers would at the same time be needed to inform and administrate the system in the purchase situation, where the deposit should be placed.

Online retailers are by default obtained in the WEEE-system as importers of mobile phones, and so would have to compensate for using the system facilities, given by their yearly sales (market share). Retailers that rely solely on online sales are estimated to have 5% market share (Grontmij, 2013: 5), showing why a 'pre-paid postage' as an alternative mail-in recycling service, could be rated as an unnecessary cost in setting up a DRS. It is therefore assumed that online retailers can negotiate lower fees with CROs ones the system becomes fully operational – hence use the saved funds to compensate operators of the DRS.

Given this, combining the efforts in a public-private manner seems most convenient, suitable and assumed most effective. This idea of sharing the "burden" could be seen as a mediator towards the previously mentioned critique of establishing collection points at the expense of retailers as proposed in the new WEEE directive (2012). Additionally, a DRS might result in a opportunity for retailers to get 'possible customers' inside the stores, where e.g. mobile phone accessories apparently had a global market value at 36b USD in 2012, while for instance the average US consumer spent around 56 USD on things like smartphone covers (ABI Research, 2012). With these assumptions in mind, a total of both possible public and private collection points have been found as followed:

Public: Accounted from the official registration web portal at DPA-system, 600 public run recycling and collection sites accepting WEEE. These are all widely spread around the country in 98 municipalities.
Private: Accounted from a wide selection of retailers, who both have physical stores and mobile phones sales, an estimated 520 possible collection points. This is not an exhaustible number, but represent official information on Danish stores from respective web sites. The stores are expected to be located in central shopping areas (Appendix 4D).

Therefore, a total of 1120 possible start-up collection points for mobile phones is estimated to be available today.

From this foundation the costs of establishing a DRS for mobile phones has then been calculated and estimated, based on a set of variables, including: "*transport", "start-up", "running", "administration and logistical", and "material" costs/per site plus overall supervision costs from public administration.* The assessment of total system costs is applied to ***Appendix 4D***, and gives an overall estimate to discuss a functional setup from, underneath.

From the base of these calculations it is found that it will cost around 8,42m DKK to build up the formal system, while the costs of running the system over a year will be 11,3m DKK. This adds up to 19,7m DKK (approx. 2,65m EUR) in the first year. The estimates are based on what approaching full system capacity with a collection rate of 90% of the estimated yearly mobile phone sales of 2m/yr. (Appendix 4D).

Initial campaign costs are not included in the totals found in appendix 4D. The costs of a campaign and general public information of implementing the system in the start-up phase could also be covered as initiated in section 6.2.1, which showed that a sufficient amount of value would be generated from collection and selling the scrap resources of historical phones. It is thus found justified that such funds would be used for this purpose, since the formal collection system hasn't proved capable of collecting these obsolete devices until now. To save costs to public information and campaigns some ideas was noted in the Norwegian feasibility study. A start-up campaign could be initiated by coupling to other main events like government elections, where people could bring their obsolete phone to the polling station. Additionally, best practice from other countries, found public-private partnerships on information campaigns coupled to general advertisement and so forth (Dag-Friis Baastad, 2013: 6) (cf. section 6.1.1). Thus, creative ideas could help bring down the costs of the campaigning and information efforts in the start-up phase.

The benefit from a societal perspective is clearly the establishment of an effective collection system, which can be expressed by the positive socio-economic value. The remaining question is then: *how to fund the system*. If we here again take a look at the DRS for beverage containers, the non-collected deposits pay for the running costs of the system (DRS A/S, 2013: c). Since, DRS can be regarded as a non-profit service initiative with a clear environmental and systemic purpose, these unpaid refunds must go to both keep the system running and also optimizing it in the future. The deposit, which the consumer initially pay, can be seen as a temporal fee, in which it will become sort of an environmental tax for those who don't collect their refund in the end, even though it is a matter of individual responsibility. Therefore, a system like this can only be justified from the consumer and retailer perspective, if the stakeholders who run the system aim and strive to achieve the highest collection rates as possible.

Therefore, with a collection rate of 90%/2m sold phones/yr. (approaching full system capacity) the uncollected refund would mount to 20m if the deposit were selected at 100 DKK, while if the deposit were 200 DKK, the funds would approach 40m[68]. The conclusions is thus that this should be more than enough to run the system in the long-term, while it also would leave room for improving the system in the future and achieving even higher collection rates closer to 100%.

A collection rate of approx. 94% would leave 12m DKK to pay for the running cost of the DRS with uncollected refunds of 100 DKK per phone. And with uncollected refunds at 200 DKK per phone, the collection rate could amount to 97%, before the DRS would need additional funds[69].

In the case of the DRS for beverage containers revenues are also generated from the recycling of e.g. one-way packaging, which have been increasing in recent years (DØR, 2013: 282). In this similar way revenues from the further sale of collected phones to the recycling industry could mount to be significant. As previously estimated in section 6.2.1 the metal resource value from one phone is approx. 16 DKK after processing costs have been paid. With collection rates approaching full system capacity between 90-100% this would equal yearly revenues in the order of 28-32m/EUR[70].

This means a couple of things: First, that funds from resource revenues could pay the running cost of the system alone, why approaching a 100% collection can be done without counting on non-refunded deposits. In justifying the system from a political perspective, towards consumers, makes this a very positive perspective. Secondly, that there would be financial room for expanding the system to other product types in e.g. the ICT sphere without needing additional funds. Finally, it is possible to fully close the resource and value cycle around the products.

In the present collection system CROs would be the natural successor of the collected phones, ensuring the further treatment, even though they do not collect any significant amounts today (cf. section 5.2). However, a DRS would create a whole new situation. Some of the stakeholders in setting up the DRS (by this meaning the retailers), would have cross-organisational relationships in this regard, being both CRO members to fulfil their extended-producer responsibility and part of the new DRS organisation.

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[68] Non-refunded deposits of 10% = 200.000 phones X either 100 or 200 DKK = 20/40m DKK.

[69] Non-refunded deposits of 6%/2m phones = 120.000 phone deposits X either 100 DKK = 12m DKK. Non-refunded deposits of 3%/2m phones = 60.000 phone deposits X 200 DKK = 12m DKK.

[70] Metal resource revenues from 1.8-2m collected phones x 16 DKK = 28,8-32m DKK

However, the CROs could still seem a useful binding link between end-collection and all mobile phone OEMs. OEMs don't necessary have any retail stores on the market and so for an example contract MNO retailers to sell their products. This situation means that a trade-off between the CRO to the DRS organisation has to be made. If the DRS organisation refrain from selling the collected phones directly to the recycling industry and instead deliver them to a CRO, the CRO could still ensure the proper treatment on behalf of all OEMs and collect the final resource revenues. And so, the CRO would then have to pay funds to the DRS organisation instead. In this way the resource and value transfer circles between all stakeholders on the market. All this being said, it would be necessary for all parties in the collection of obsolete mobile phones to assess a reasonable trade-off system divided by their common EPR obligations, costs of running a DRS based take back system and the transfer of the reclaimed value from scrap-resources.

The conclusion is that it creates some interesting perspectives where OEMs can become more directly engaged in the EOL phase, if CROs cooperate with their members to manage the further treatment. In this way it would become possible to setup pay-as-you-scrap systems (as described in section 5.2), since control with the resources are re-established. In an overall valuation is that there is found no significant economic obstacles in setting up and running a DRS for mobile phones. Thus, both from a private and socio-economic perspective a DRS would have a seemingly very positive outcome.

6.2.4 Information

The final key to obtaining a good an efficient recycling system and to possibly get satisfactory recovery rates in the future, works around information transfer. Both in the perspective that OEMs could engage in the EoL phase but also for getting the practical system to work. When people purchase a new phone, they will need to place the deposit at the same time. The deposit will need to be transferred to the DRS Company and 'kept' until the phone is handed in at a collection point, where the refund can be paid out. For this to work, mobile phones must have some sort of information attached to them. Especially in the first many years, the possibility of mixed collection of phones with and without deposit would be evident.

In the beverage container systems, standardized refund marks is added in the production phase, while the barcode also function as to scan the products in the refund machines (Rehnberg, J, 2010: 13). To transfer this method on to mobile phones would be both difficult in terms of fighting product design aesthetics and probably an unnecessary hassle. A deposit certificate is another option, where this could be given out with the purchase in paper and electronic form. In many situations the store staff would already need to deliver subscription contracts at the same time, while in the case of online retailers it can be packed in the postal box, while also being sent out together with the electronic invoice. What is a bit problematic about this type of method is that the certificate can be lost both in paper form and electronically. It will also make it more problematic for consumers to resell/give-away their phone to a third party on the second-hand market, since this certificate would be needed to circle around in society, together with the phone. This means a separate DRS database so that deposits can follow the phone no matter where it travels in society – locked on the device.

However, devices like mobile phones, some tablets and notebooks (which have mobile network capabilities) are all registered in the *International Mobile-Station Equipment Identification – Database* or in short the IMEI-database. The IMEI code is a unique serial number that all mobile phones are born with, consisting of a 15-digit number, which not only includes the serial number information, but also the name of *"manufacturer and the model identifier of the associated handset and some of its technical capabilities"* (GSMA, 2013). All MNOs have been granted access to this database along with some industry parties and regulatory authorities. The database is maintained and monitored by the GSMA[71], which also provide black list options. This means that if a mobile phone gets stolen or lost, it can be recorded in the system and so the phone can be banned from access to any network in the whole world. Here, for instance network operators keep their own equipment identity register, which can be updated on a regular basis (ibid.). Keeping a register of IMEIs with deposits and the opportunity to delete them automatically would be essential here - both for the general day-to-day function of the DRS, but also in this case of theft. The IMEI code will always follow the phone and so it will be rather easy to build a digital database system where you can attach, ban and detach the deposit based on this unique information. This would also enable intelligent features where automatic reminders *on the refund* can be sent out as SMS to the phones or as e-mail, when it reaches a certain age (e.g. 3 years after purchase).

The number is placed on the invoice from the purchase, physically under the barcode of the battery of the phone and on the product box, which it came in. The code will also appear on the display if you type *#06# (TDC, 2013). Additionally, MNOs already have to grant access to the device and so will possess a record of it, even if a person shifts provider for his or her device. Many people will maybe give away or sell their used phone to a friend, family member or on the second hand market. In this case, the invoice will not necessarily follow the phone. Also, if the phone becomes damaged on the screen or can't be recharged, the only option is to open it and read the code from under the battery. This might be tricky concerning todays phone designs[72]. It will probably be impossible to require OEMs to e.g. lazer tag[73] the IMEI-number on the mobile phone casing for a single market, but in a European context this might be a durable solution. If design for disassembly become more general in the future, it would properly also become easier to read the physical print of the IMEI code inside the phone. However, a number of semi-problematic and practical situations have to be dealt with here. This doesn't change the fact that the IMEI-number seems the most obvious choice for attaching a deposit. In the Norwegian study they questioned the problem of sensitive and personal information on these mobile devices. Right now it is the owners responsibility to secure the deletion of personal data on the device. This can be a problem, where people will refrain to hand in the old devices, simply because they wont risk the data getting stolen (Dag-Friss Baastad, 2012: 32). This can't be a task for the staff at the collection points, why a safety

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[71] *Groupe Speciale Mobile Association*

[72] As was noted important in section 5.5. New parameter such as Design for Disassembly was needed, but can't be expected in the first many years of a DRS system, and only in the case of trans-European adoption of similar circular system approaches. This would require OEMs to engage and introduce new more adequate designs for efficient recycling.

[73] For example Apple Inc. already provides free lazer engravings on their products the "iPod" and "iPad", why it is seemingly a durable solution (Apple, 2013: [b]).

measure of full recycling and termination of the collected devices must be ensured. A single safety precaution could be to make the staff at the collection point, take out the SIM and memory cards for secure disposal. Nevertheless, internal product memory will still be a problem. However this initially means no reuse market would be directly justified for devices collected through a DRS.

6.2.5 Scenario Design

So how would this system scenario look in practical terms? Anticipating a future scenario with a 90% collection rate (return) of the approx. 2m phones sold a year, would follow an average 5-6 phones a day per collection point (Appendix 4D). This means previously mentioned suggestion of automatic refund machines (cf. section 6.1) seems largely as an unnecessary cost. Therefore, costs of labour for manual service and handling at collection points were also included in the estimates for administration (Appendix 4D). Here a simple digital solution for attaching deposits and paying out refunds thus seems sufficient and while day-to-day handling would be using simple designed and dedicated collection boxes easy for transport (Appendix 4D). Deposits would be placed in the purchase situation (at the store based or online retailer) and so refunds would be paid out at collection points. It is assumed that very few collection points, especially public ones, would have cash systems on site. In this regard reversed pay methods (on credit card/or mobile wallet) or receipts that could be redeem from a website/web-bank would be most logical to use. The final system characteristics of this DRS design scenario, can now be viewed in figure 24:

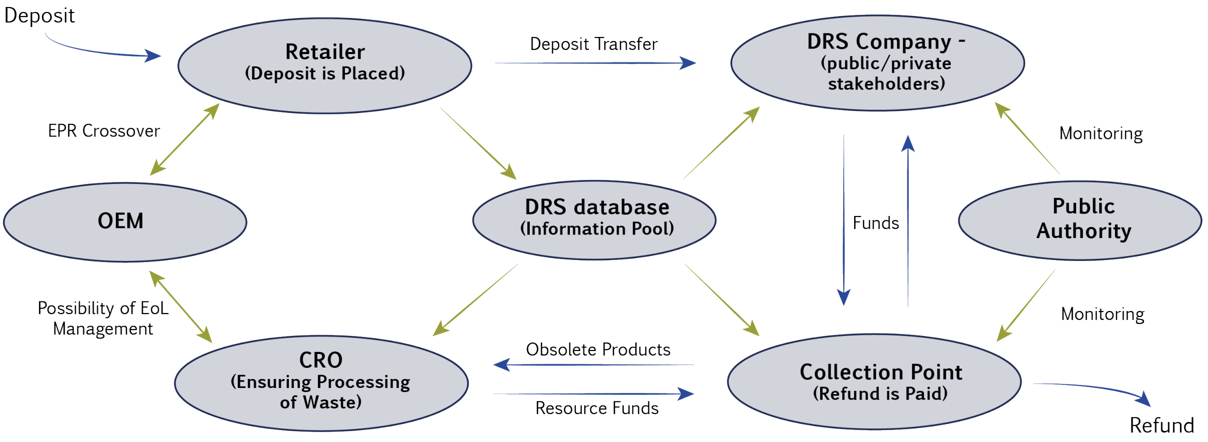

Figure 24: '*Scenario Design for a DRS on Mobile Phones'*. Blue arrows represent resource and value transfers. Green arrows represent information transfer. The scenario reflects a national DRS collection system, created as a public/private initiative. The DRS Company would in this scenario be run and represented by the implicated stakeholders that normally sell and collect phones. This would include online and store based retailers, public collectors. Public authorities would monitor the system and ensure transparency. The DRS database creates an information pool, which can finally be used to guide the now detailed resource flow to optimal processing routes in the EoL phase. In this way OEMs will gain a unique opportunity to engage, manage and control these resources. CROs would now have to pay funds for the obsolete phones they receive on behalf of their OEM members. The OEM will have a crossover role, since some of the commercialised products will be sold directly by affiliated retailers and some by external retailers - for instance by MNOs. However, since individual take-back systems registration is an option under the WEEE-directive, it is possible that some so-called 'producers or importers' would regard this as a better option. Therefore, the point behind the inclusion of CROs in the system design is that they have the ability to provide a final administrative and logistical hub between OEMs and various distribution and collection channels.

6.3 End-of-Life Management

In this and the next sections we will now be looking into EoLM as a strategic initiative to follow a collection system like DRS, taken place on a given market. Managing the EoL of products is therefore regarded as a logistical and strategic operation done by OEMs. Traditionally supply chain management focuses on getting products to end-users, beginning with raw materials and ending with consumption - EoLM, is about bringing the resource flows of obsolete products back in the supply chain (Harold, M., 2007: 17). This includes the reuse of the full product, the components or processed resources possibly through refurbishment, remanufacturing and recycling, or, simply ensuring responsible disposal (IPPTel, September 2007: 27). A definition list of these recovery options is provided in Appendix 2H. That means EoLM constitutes establishing a foundation for making a profitable operation (making valuable use of obsolete products, components and end-resources) while also increasing sustainable operations within the individual company. Managing this end-flow of products is also referred to as *reversed logistics* (Harold, M., 2007: 18). Additionally, it will be the foundation for documenting and using the achievements in strengthening the company profile (branding) on the environmental and social side of its operations. Here, a commercial perspective is evident, while society and nature benefits as a whole from less waste and less use of virgin resources. The responsibility for taking on EoLM, is naturally placed on the companies who have the EPR, in correlation with the products they put to market (cf. section 5.2). For the OEM this means controlling the resource flow of obsolete products from individually take-back strategies or cooperating with CROs to finally establish efficient recycling, reuse or remanufacture operations. However, EoLM rely on efficient collection systems to gain scale, where a combination with a DRS[74], would be seen as a way to facilitate greater amounts obsolete products (EMF, 2013: 39).

6.3.1 Experiences and Perspectives on EoLM

According to Erik Sundin, OEMs are striving to increase their revenues and profitability, controlling a larger market share and a larger part of the product value chain. As markets mature, it causes the companies to seek more value in the whole life cycle and especially in the 'use' and 'EoL' phases. Opposed to today, where added product-value comes from *"...technological improvements and non-material aspects such as intellectual property, products image and brand names, aesthetic design and styling"* (Sundin, 2010: 2f). Approaching the circular and sustainable path, corporate operations must then go beyond these normal parameters.

In this regard it is here sought make examples of some past and present activities in the telecommunications industry. Nokia have for some time and is today a market leader in environmental and social corporate responsibility operations (cf. section 5.3.5). They build their own reversed logistics operations on repair and partnerships with recyclers (Nokia, 2012: 89). Nokia introduced some EoLM strategies around 2002, taking

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[74] Not excluding other possible take-back operations that haven't been analysed in this report.

back phones from their worldwide network of service centres. Here they obtain spare components, make repairs or send the collected phones for regionally appointed recycling. However, most of the returned phones are only worth their resource value (Harold, M., 2007: 220f) and here assumable going directly to recycling operations. Globally, Nokia run recycling campaigns in 20 countries based on partnerships and reportedly collected 423 t of obsolete phones, batteries and accessories last year (Nokia, 2012: 89). However, Nokia have not been found engaged in refurbishment for reuse activities as far as this thesis goes. Despite of their good history of cannibalizing spare parts for phone repairs in warranty cases. Problems to engage more, arise from low direct sales, which is done mostly by MNOs and from the fact that refurbishments for reuse activities would need stable reversed flows of high-quality used products (Harold, M., 2007: 221). In the case of supply chain management, Nokia clearly focuses on monitoring and integrating strong corporate policies on environmental and social issues on site. In terms of resources (raw materials) they solely focus on trying to source conflict free metals in collaboration with the industry, though they do not buy metals directly and express the difficulty of having 4-8 supply layers underneath them. They see it as a complex task and hard to trace metal supply chains (Nokia, 2012: 126). And so this, and other environmental and social concerns in their focus area, is not addressed through use of more secondary metal resources.

Returning to the option of refurbishment. At least two MNOs ‘O2’ (Telefonicá) and ‘Vodafone’ in the UK, have resale of refurbished phones. O2 directly on the homepage[75] while Vodafone[76] has an online store on Ebay. Likewise, Apple[77] has also provided refurbished sale of some of their products for some time. McKinsey & Co. has calculated some basic economic perspectives on a circular scenario case for resale of refurbished mobile phones (EMF, 2013). Mobile phones today (smartphones) have an average market value of 400 USD with top prices ranging in 600-700 USD. OEMs are typically having material component costs in the range of 100-130 USD, where most of those costs stem from technological advancement and software development around these. Here, the point is that: *“Depending on a device’s condition, resale after refurbishment is a viable business opportunity as secondary market prices are estimated to be up to 60% of the original price”* (EMF, 2013: 43). This generates a positive incentive for reuse on nearby markets (Europe). As an indicator for the business opportunity to this approach, McKinsey & Co estimates that a refurbished phone could generate profits in the range of 100 USD per phone, after initial costs have been paid (ibid.)[78]. Additionally, it would maybe here be possible to address issues of overstock, flawless devices from damaged product packages, in-store display devices and devices with cosmetic flaws, by running them through a certified refurbishment process. In the case of a DRS on mobile phones and the problem with sensitive data (cf. section 6.2.5) a refurbishment program could also ensure safe data destruction.

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[75] See. https://www.o2.co.uk/shop

[76] See. http://stores.ebay.co.uk/thevodafonemobilephonestore

[77] See. http://store.apple.com/us/browse/home/specialdeals/

[78] “The costs of refurbishment are not insignificant—replacing the display, camera, battery, and casings of a smartphone adds up to material costs of around USD 45,66 and associated treatment costs, including collection, transport, screening, executing the refurbishing process, marketing the refurbished product, and other administrative costs would add another USD 45” (EMF, 2013: 43).

It is here required to establish or engage in B2B operations that can facilitate information and flows of obsolete products and components logistically to and from the OEM or an external retailer. This includes: generating knowledge about e.g. the collected amount of obsolete devices, different models and their condition. Here obsolete products coming from a collection system like DRS or another take-back operation, would go through a *service provider*[79] that can elaborate and distinguish between fully broken and still valuable devices and their respective components. Though some devices will go directly to recycling or be cannibalized for remanufacture operations, others may go to refurbishment operations for a reuse market. Here, the design parameters such as easy to disassembly and recycle, that was found needed to obtain good end-results and high recovery rates of metals as examined in 5.4, seem to somehow correspond well with the technical damaged experiences: In the consumer survey, respondents answered that technical flaw/damaged displays, batteries, casing and microphone/speakers to be the most common problems (Appendix 5A: Q19).

Apart from refurbishment for reuse, remanufacturing of valuable components is that extra option. This means, OEMs would use the service provider to remove desired components (e.g. microphones, speakers, microchips, screen parts and so forth), which can be tested, sanitized and then shipped to a supplier for product manufacture somewhere in the world, without ever having to go through the full recycling stage (of pre and end-processing). This could enable OEMs to save costs of pre-manufactured components, while the resources can remain intact and the components can be revitalized in new product life cycles. Additionally, the Ellen McArthur Foundation also explains that:

> "From the OEM perspective, the resale market is to a certain extent a threat to sales of new products. In contrast remanufacturing activities on a component level reduce material costs by incremental manufactured components and will not pose a threat to sales of new products as long as the latter are offered as 'new' and without a discount. Such circular business practices also offer a solution to the widespread problem of exporting consumer electronic waste and improper end-of-life treatment in developing countries." (EMF, 2013: 41)

However, the future challenge to remanufacturing operations will clearly be to recapture valuable components, where design efforts for easier disassembly will somehow determine its profitability – approaching more circular product patterns. Additionally it has previously been analysed that some major mobile phone OEMs see the time lack, which long use phases naturally creates, hard to unify with the fast technological development in the sector. Recaptured components will quickly become out-dated (Harold, M., 2007: 98). It is therefore maybe most convenient for OEMs to recapture metals from the recyclers and direct them to suppliers.

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[79] For instance, Sohnen Enterprises Inc., which is a California based company, provides such B2B services reversed logistics on refurbishment, and asset recovery, on behalf of companies in the consumer electronics industry. See their business models here: http://www.sohnen.com/ServicesWeOffer.aspx

From this perspective it is thus maybe more likely that retailers, especially external ones, approach the second hand market with refurbished phones to increase their individual profitability. Respondents in the consumers survey here drew a picture of a rather large second hand market, where 25% would prefer to obtain or purchase a used mobile phone, and 33% reported to have done exactly that with their present primary phone (Appendix 5A: Q6-7). This means, opportunities are out there.

Nevertheless, what can be concluded is that operations for primary direct recycling for recovery of metals seems most convenient for OEMs – also from the perspective of leaving room for continues technological development of products. That being said, increased take-back and control with obsolete devices, possibly through a DRS, would enable OEMs to approach valuable recovery operations of various kinds. Here, the information transfer from such a system, creating stable and detailed flows, could enable them to approach design for disassembly and recycling – not only for a recycling endeavour but also for easy repair, refurbishment and recapture of valuable components.

6.3.2 Opportunities and Ideas to Push for EoLM Operations

Managing the EoL of products is somehow a customized operation, which all OEMs have to develop in single or joint ventures, around a pre-collected e-waste fraction. However, three opportunities emerged from the analysis of ideas to push OEMs to obtain EoLM operations.

The first idea; is to create network and B2B service relationships between OEMs and recyclers. In the interview with Christian Hagelüken, we then discussed the possibilities (Hagelüken, Appendix 5B: min. 23-33). Hagelüken explained how Umicore (and also their competitors) were already practising end-of-life services for the oil and chemical industries, where e.g. catalysts (which has a high content of precious metals) are simply sub-contracted for processing and where the metals are returned to the company to use in new production processes. In this way the valuable metals remain the property of the company (OEM) and thereby just turned around in loops for new production processes. According to Hagelüken, this approach was not present in the electronics industry today (ibid. min. 23-26). This idea of a service approach on contracted processing would enable OEMs in the electronics industry to use the European recycling industry as a final recovery and refining step before eventually shipping the metals to e.g. dedicated suppliers overseas. This could for the larger portion of obsolete devices be the point of intersection, which would lead down the path towards a circular economy, explicitly named in these reflections:

- Sub-contracting recycling operations could enable OEMs to bypass most of the environmental (GHGe, natural destruction, pollution from mining and refining activities etc.) and social challenges (conflict metals, worker rights etc.), which takes place in the pre-manufacturing stages of the product life cycle (Appendix 3D).
- Creating measurable, viable and valuable metals yields to drive the production phases of new products, bypassing the challenges of geopolitical conflicts around metals and hedging costs on the world market

of metals for its suppliers, securing future delivery and cost reductions to new product lines (protecting against volatility metal prices) (cf. section 3.2.1).

- Creating a foundation for OEMs to help optimizing recycling efficiency by cooperating with implicated recycling companies on developing e.g. products designs for disassembly and efficient recycling in for the future.
- Strengthening the corporate sustainability profile significantly, by using new gains from recycling and recovery operations commercially to market new product lines (with better sustainability profiles) (cf. section 5.3.5).

The second idea; derived from the regained possibility of using such circular and sustainability operations in a commercial sense. Marketing of 'sustainable' or 'environmental friendly' product will unquestionably be attempted by any OEM engaging and establishing in such quest, for obvious and good economic reasons. Here risks of green washing could mount to be a very counter productive side effect (Hagelüken, C. Appendix 5B: min 27). Therefore, it is important to establish the right conditions and verify that the recovered metals *actually go in to new devices*, preferably of the same type (metals from old mobile phones to new ones, or at least other devices in the company's given product portfolio – mp3 players, tablets etc.). Mixing metals with recycled gold from the jewellery industry or aluminium from old beverage cans, can easily make the product "look" very sustainable, without ever being so (ibid: min. 30). It can be argued that no matter what metal and where it comes from, a recycled one limits the uptake of virgin materials. However, the point, which Hagelüken also initiated, is that the picture could be misleading because it would drive virgin resource uptake somewhere else on the market - the so-called rebound effect (cf. section 3.2.2). It is very easy to get a high total percentage of 'recycled metals' in a product if there is no distinction between base metals and precious/speciality metals, simply because of the weight distribution (cf. section 5.3), which is why such measures must be very transparent and made mandatory to be conveyed publically.

Another problem might emerge if OEMs engage in joint EoLM operations e.g. between several different mobile phone manufactures, then detailed information flows on collected obsolete devices from each market would be necessary to distinguish corporate property rights for the final end-recovered metals along with precise metal recovery estimates from the recycler. Otherwise, the idea of sub-contracting becomes very complex. However, this might be a fruitful solution for some OEMs - since they would often share same component manufactures (suppliers) - by streamlining operations and benefitting logistically from economies of scale.

So how could green washing and such difficulties be prevented? Obviously the OEM can integrate appropriate reversed logistics management and make transparent resource-to-product flows in the EoL phase, fully by themselves - based on sub-contracting recyclers to process collected resources and finally trading the metals back to its suppliers. However, in order to safeguard that corporations are not misusing the systems to green their product portfolio with e.g. materials from other industries, a third party process certification scheme will be an appropriate foundation in a circular market approach.

Hagelüken fully acknowledged a need for certification and also mentioned a proposal from the European Non-Ferrous Metals Association (Eurometaux), which Umicore had partnered to develop, presented to the European Resource Efficiency Platform last November (2012) (ibid: min. 31f). This proposal reflects some strong statements based on a full life cycle approach to metal products, and is divided into both success and risk factors (Eurometaux, 2012). In this regard and in relation to efforts for a "circular economy and recycling", they presented these two initiatives as safeguards:

- "Setting up of a mandatory certification scheme of end processing/recycling facilities to ensure that secondary materials may only be exported if a final processor is duly identified and certified based on criteria related to environmental, health, governance conditions and process efficiency" (Eurometaux, 2012: 1)
- "Facilitate the identification of potentially illegal shipments i.e. a risk matrix to identify the most risky shipments (exporter and destination) and proposal to add customs codes to distinguish second hand products from new products (many illegal shipments are disguised as 2nd-hand goods)." (ibid.).

Additionally, as noted above, Eurometaux also included other success factors like: pushing "industrial innovations strategies" and setting up a "centre of excellence on supply chains" under e.g. the European Commissions 'Joint Research Centre' (ibid: 2). Leading industries in a sustainable direction and creating knowledge about processes throughout the different value chains.

Important positions against future risks, included precautions to insufficient indicators and targets, by: focusing on country specific data, including a utility measure instead of only resource efficiency on metals and also the use of indicators that accounted for resource functionality instead of only weight based targets (ibid: 2) [80].

The third idea; is based on the involvement of consumers. With these process certification opportunities in mind, OEMs are still only *possibly* willing to build logistical setups for managing and controlling the EoL metal resources; nothing in the present EU WEEE regulation can force them to do more than fulfilling their EPR obligation - *Proper Treatment 'Article 8'* to the WEEE Directive, (2012). To create incentives to first engage OEMs in sufficient take-back and collection systems, e.g. through a DRS, and to further take-on EoLM, the role of the consumer and new information obligations to OEMs might be that durable solution for decision makers outside the corporation.

In relation to this discussion, the final questions in the consumer survey reflected how the respondents related with the available product information today on the environmental and social profiles for mobile phones. In the first question, they were asked if they felt they received the correct information in a purchase situation. In the

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[80] Additional, Eurometaux mention problematic market conditions with new unilateral resource taxation methods across Europe and green washing alleys with "saved" CO2 emissions around resource certificates, which both could be counter productive.

second, they where asked if the correct information could make them "consider" one product over another. The result gives a very convincing signal that the respondents unanimously feel a lack of correct information around mobile phone purchase. Secondly, that additional information would have an effect on their choice with a high certainty, given that only 5% said "yes" (believing they already had the information they needed - Q22) and only 4% said they wouldn't change their mind about a product (Q23). See figure 25:

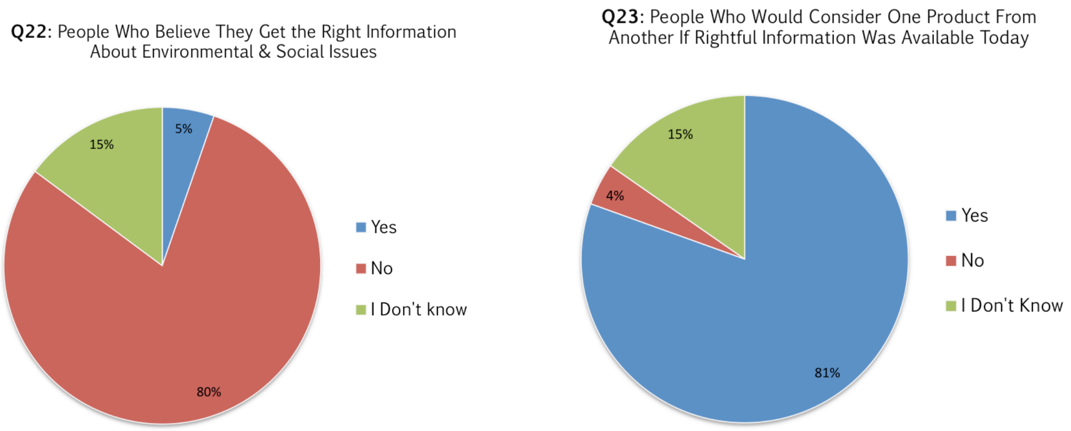

Figure 25: 'Consumer Perception About Rightful Information in a Purchase Situation' & 'Consumers Who Would Consider One Product From Another With Available Information'. (Appendix 5A: Q22 + Q23)

Preliminary speaking; going to most physical retail stores or web stores for mobile phones today, seemingly does not reflect visible product specific information on these issues or many times any information at all[81]. This is probably why most informants responded this way. However it cannot be certain that consumers would necessarily 'act' differently in a real life situation, though a very large amount responded they would. This is due to the fact that the respondents, at this point of doing the survey, maybe had started to sympathize with the heart of the subject or subconsciously responded, 'yes' because it was an easy "feel-good" choice with no liability. Nevertheless, in the very first thematic question the respondents were asked to rate different preferences for purchasing a mobile phone, as seen in figure 26:

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[81] The eco-profiles examined in section 5.5, were found on OEM websites while examining multiple drop down menus. During the course of this project, almost all Danish and many foreign web stores have been browsed for information, plus Danish physical retail stores have been visited, giving this final picture.

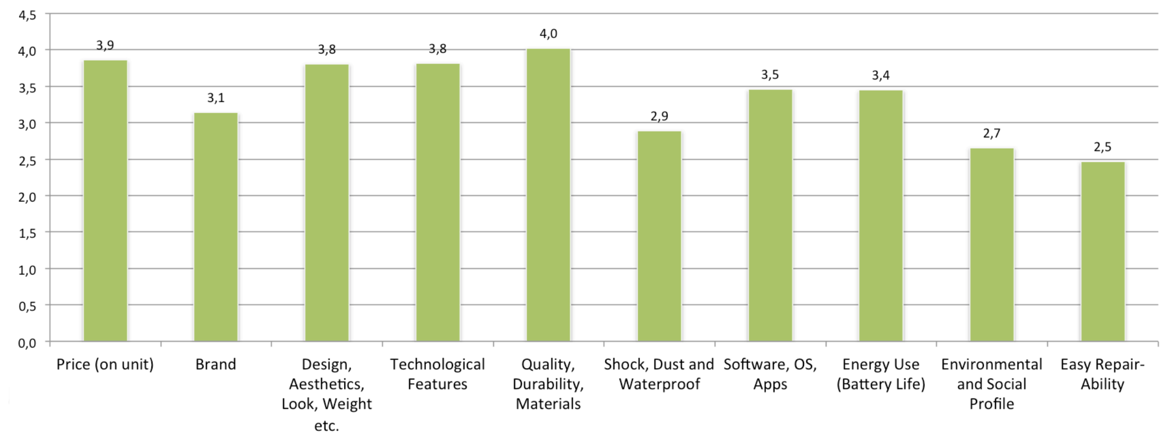

Figure 26: ‘Personal Preferences When Purchasing New Mobile Phone’. Based on a 5 level scale - where 1 is less important and 5 is very important (Appendix 5A: Q5).

This result somehow showed that people’s choice of product might be initially determined, for example, price to some extent and heavily dependent on the look, feel, smoothness, experience and other image & sense-based parameters of the object in hand. This is expressed by the survey informant’s high ratings of ‘*design, aesthetics, look, weight’*, *‘technological features’*, *‘quality, durability and materials’* and also *‘software’* as perceived important features for selecting a new mobile phone. With the survey results in mind, this also means that special device properties such as it being *‘shock, dust and water resistant’*, *‘having a positive environmental and social profile’* or being *‘easy to repair’* can be seen as additional product values. Therefore, these cannot determine the purchase alone, if the product is not strong in the first key areas, but might be important pushover incitements, which can lure some consumers to finally choose one product over another.

In reviewing the obstacles and possibilities of pushing sustainable production and consumption patterns, Kate Power and Oksana Mont (2010) find consumer behavior to be not only complex, but also largely misunderstood by decision makers today. Through dispelling of what they term ‘myths’ about consumer behavior, they disprove that eventually *“more information should lead to sustainable behavior”* (ibid. 2010: 2). Backed by a long history of studies, Power & Mont emphasize that the idea of rational “economic” humans is questionable and that humans are largely affected by emotions and habits, choosing not only individually but are also influenced by the social context and collective norms in society. Behavior is not consistent with attitudes and values, creating a gap (ibid. 2010: 3). However, Power & Mont don’t consider information to be unimportant, but should be backed by a clear vision for the future (ibid. 2010: 4). This position compliments another so-called myth, that *“consumer should lead the shift to sustainability”* by raising public awareness, instead of developing more effective tools, like administrative and economic instruments (ibid. 2010: 11).

Taking these considerations in to account, it is important to broaden the spectre of what sustainability information can accomplish in terms of pushing OEMs to engage in effective collection systems, use new business models or create incentives that push more circular EoLM operations into existence. It is important to recognize that even if only e.g. 10% of consumers would act differently in real life, it would be a strong action incentive in such a competitive market as that of mobile phones. Additionally, this viewpoint can finally be backed by a study done by O2, where 44% of their UK customers stated that sustainability information would have some influence on their purchase decisions, while 11,5 % said strong influence (O2, Eco-ratting, 2013: 1f)(ITU, 2012: 8).

Therefore, making international systems for product specific sustainability profiles on mobile phones, would possibly **1)** give consumers a chance to actually compare one phone with another, and **2)** give civil society the opportunity to pressure OEMs on their achievements, give investors[82] a tool to navigate through corporate sustainability profiles and lastly, government authorities the chance to develop appropriate regulations tools.

Lastly, the respondents in the consumer survey were asked how they saw this information to be shared. Not surprisingly, the respondents largely wanted additional sustainability information to be easily presented (eco-labels/ratings) and where they needed it – directly in the store or web shop (next to the product display) (Appendix 5A: Q24).

So are such sustainability information systems initiated and, if so, do they contain sufficient information? The answer is both *yes* and *no*. MNOs including AT&T, Orange, Sprint, Telefonicá (O2) and Vodafone, have in recent years started to make their own so-called eco-rating systems for individual mobile phone models, (ITU, 2012: 36-41). O2 has established an eco-rating system as a way to meet increasing information requests from their customer base and to strengthen their own corporate sustainability profile (O2, Eco-Rating, 2013: 1). Likewise, Vodafone says their eco-rating system *"enables customers to compare the environmental and social impacts of different mobile phones so they can make an informed decision in choosing a more sustainable phone"* and *"we aim to encourage manufacturers to design and produce more sustainable phones"* (Vodafone, Eco-Rating, 2012: 1).

Despite these humble and seemingly progressive intensions and that the MNOs partner and cooperate with third parties (NGOs and consultancies) to develop these rating systems, the first main problem is that they will not be/are not consistent with one another. For instance, AT&T, Telefonicá and Vodafone base their systems on optional survey questionnaires submitted to the OEMs (pre-commercialisation)(ITU, 2012), with a matrix from 15 (AT&T) to 162 (Vodafone) questions spread into an un-similar amount of evaluation categories and rating methodologies[83].

Secondly, mobile phone models then end up having an overall eco-rating score that, at least in the case of Telefonicá and Vodafone, is rated on a 1-5 point scale and expressed by e.g. '2.3' for a given phone model. These ratings then constitutes to an overall value, which is easy for the consumer to compare, but does not

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[82] In two recent reports from PricewaterhouseCoopers they point out the importance of corporate sustainability profile to investors. That corporate financial success goes hand-in-hand with long-term sustainable progress and community well being (PwC, march, 2012: 7)(PwC, July, 2012).

[83] E.g. see categories and methodologies for O2, Eco-ratting, (2013: 5-8) and Vodafone, Eco-ratting, (2012: 2-3)

deliver on more specific details. Vodafone on the other hand, has established a fairly large and seemingly thoroughly questionnaire based on life cycle assessment through the ISO 14040 standard, calculated and verified by a consultancy. By using this system and strengthening the criteria over time, they want to aspire and reflect progress in the industry (Vodafone, Eco-rating, 2012: 2). That being said, the LSA approach uses a prerequisite of 'resource extraction' in their first category and then does not fully reflect a more circular approach - despite values given for EoL progress on reparability, recycling and recovery of materials in their last category. This means that a distinction on virgin versus recycled materials use, divided into *base, precious and specialty metals*, would be necessary to reflect progress, instead of only how efficiently or little raw materials an OEM has used in a given phone model. The closed nature of these rating systems, does not give civil society and public decision makers a chance to evaluate and push OEMs to progress in the future; plus the embedded optionality has until now made it possible for some OEMs to refuse and not submit data[84]. With these reflections in mind, some additional key features would be necessary to approach a more sustainable measure to act upon in the future, including:

- A maybe joint eco-rating program established and developed by a large segment of the main private stakeholders (e.g. by most MNOs joining together) or by intergovernmental bodies (in this scope, preferable the EU) – creating consistency in the system, easier usefulness for consumers and a common push from a large international market.
- A combination of easy comparable values like the 1-5 point scale system for consumers and then more public quantifiable data on pre-set parameters that can be strengthened over time and reviewed by civil society, investors and public decision makers.
- Including a circular resource-based criterion that holds a comparison of both the amount of virgin and also separately recycled base, precious and speciality metals that a product contains. This should compliment the above-mentioned idea of process certification, so OEMs must document how many new and how many recycled metals have been used in a given device. LSA scores for a given eco-rating will then also improve over time if OEMs manage to deliver higher and higher content of recycled and recovered metals in devices (and certainly also other materials as well) and simply drop other negative values like water use and GHGe from the pre-manufacturing phases, which would be bypassed by the increased use of secondary raw materials (metal resources).

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[84] E.g. OEMs in Vodafone's eco-rating program are not obligated to submit data Vodafone, Eco-ratting, (2012: 4) and for instance a large OEM like Apple is not represented yet on the scoreboard (present writing).

6.3.3 Scenario Design

It is now possible to draw a scenario design for the EoL phase, where OEMs can take part in securing resource and value flows back into their supply chain. Initiatives to push and enable OEMs for increasing EoLM operations are applied to the figure.

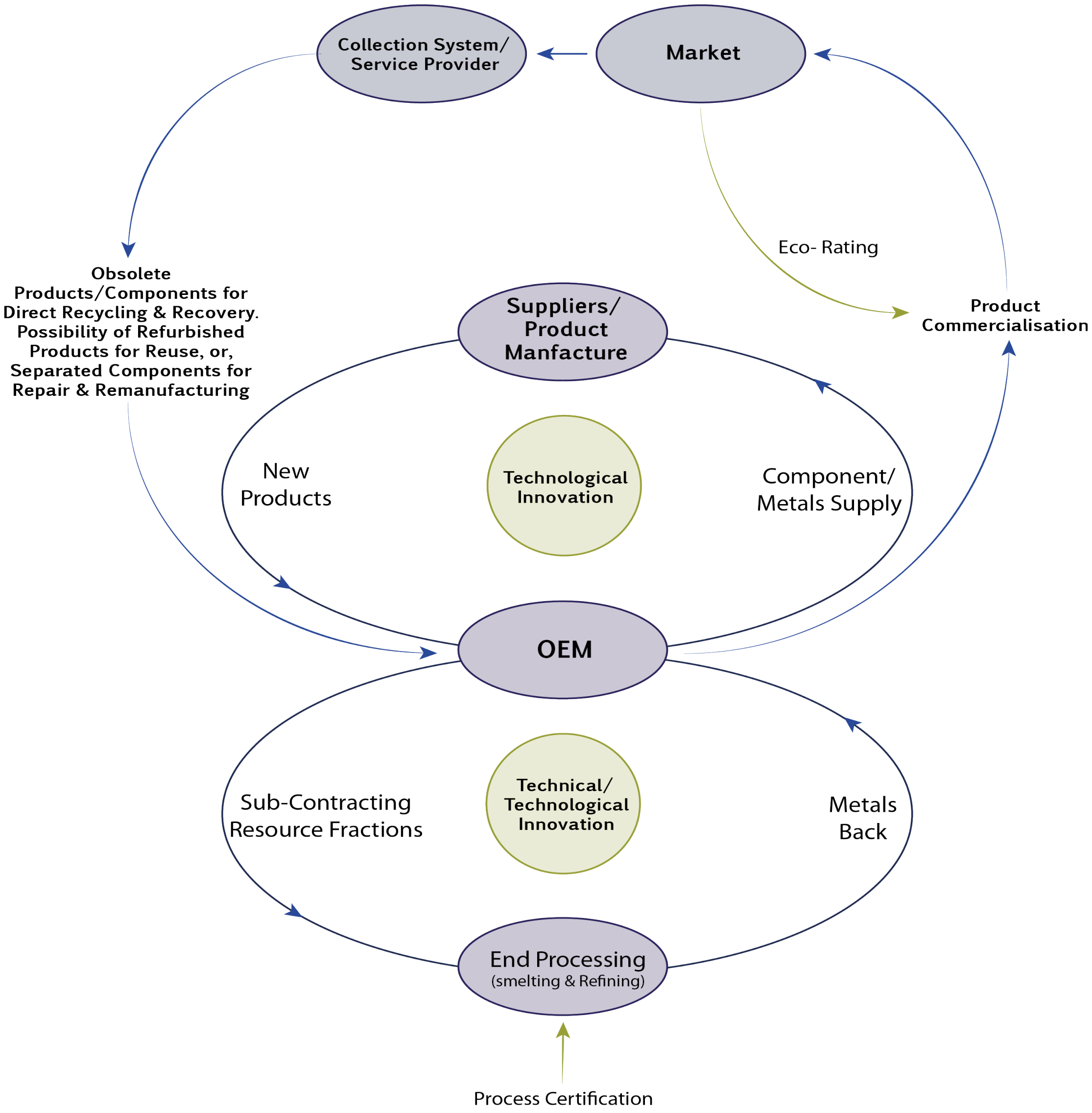

Figure 27: *'Scenario Design for EOLM'*. Blue Arrows represent information, resource and value transfers. Green arrows represent where transparent and official information is needed. If a stable and detailed flow of own products were established, it would give OEMs the possibility to strategize for finer resource recovery technologies. Such long-term eco-innovations in technological development is expected take place between the OEM and its suppliers, thus maybe approaching separable and biodegradable components as described in section 4.1 (and Appendix 2A). The presently needed technological innovation in the recycling industry, such as DfD og DfES (especially designs for disassembly and recycling), would instead be initiated by the establishment through new network and service relationships between the recyclers in end processing and OEMs. Here, sub-contracting of scrap resources play a key-role to ensure property rights and control with the metal returns.

7. Impact Evaluation of Scenarios

This chapter will reflect both discussion and evaluation of the scenario analysis of a DRS and initiatives for EoLM carried out in the previously chapter (6) merging with the findings in the sustainable gap analysis of chapter 5. This is done in correlation with the methodological approach where a final of ten 'sustainability goals' were concluded and assembled. It is thus sought to define how these scenarios and possibility new initiatives actually correlates with closing the sustainability gaps that could lead to closed loops around metals – here a qualitative comparison is provided (Robinson, J.B. 1990: 838). However this will first encounter a consolidation of the scenario results (Robinson, J.B. 1990: 837). Here an examination of the overall circular dimension and sustainability perspective is needed and is submitted underneath as a qualitative and rich text description (Robinson, J.B. 1990: 838). Finally, from the base of the backcasting methodology it is attempted to evaluate the analytical findings against the vision and objectives (cf. section 4.2) and thus select as set of recommendations for the future (as mentioned in section 2.2.1, 2.3).

7.1 Qualitative Consolidating of DRS & EoLM Initiatives

The analysis scenario indicated that a DRS could combat one of the main problems by addressing the very low collection rates, here seen through the example of obsolete mobile phones. The experience from other DRS settings, have proven that this systemic model is very promising when it comes to establish final end-collection. Additionally, the intuitive nature, where consumers are given a simple monetary incentive for correct disposal, can be regarded as the main asset in this approach. This became verified by the positive indication from respondents in the consumer survey. Additionally, not only are resources and value transferred to the EoL phase but information is also created - possible also very detailed with the use of IMEI data services. However, a DRS cannot promise that the regained devices will be effectively recycled hence that most metals will be finally recovered and go into new ICT products. Once the collected resources are transferred to the EoL phase technical/technological innovation and eco-innovation will be determined by future cooperation between e.g. recyclers and OEMs as well as OEMs and their suppliers.

The analysis also showed that the success of a DRS would be determined by the cooperation between public and private stakeholders – all engaging in its creation to promise consistency, transparency and especially in providing a wide logistical and effective network of collection points. However, in other national settings an e.g. solely private system setup might also be found as viable option due to maybe other social and infrastructural settings, thus further assessment would be mandatory. Furthermore, it is also hard to know how consumers would react outside this national context and most likely outside similar country-specific settings where DRS's are common in other circumstances (Northern European countries including Scandinavia and Germany).

The overall challenge is to make a DRS that all stakeholders can perceive valuable. Therefore, this is highly expected to be a matter of making the system features as simple as possible, both in a logistical manner but also with regards to external communication. In this light making a DRS that is both easy for consumers to accept and to use, would be essential. In this light, there is a huge difference between what the socio-economic recycling value is expected to be from a single mobile phone device, compared to what people attach to it in terms of personal value and especially as a secondary phone. This also means a DRS was found to be most appropriate and effective if the deposit size were approaching 200 DKK (in the area of 25 EUR). However, the analysis shows that most people would accept it and also see this as a fair value. The problem is to politically convince the rest of the stakeholders that this deposit size seems required for success. In this manner, it is found necessary to compliment the analysis with further research, especially to conduct a more representative result than this study has been able to provide. Nevertheless, the benefit of establishing a DRS for mobile phones is found very convincing compared to the estimated administrative, logistical and material costs of setting it up.

The time horizon obviously given by one, two or maybe more use phases per device, makes it hard to expect immediately and measurable success, but on the other hand secures an economic incentive for consumers to recycle throughout an extended life cycle on the second hand market, no matter where the device travels in society. However, this still means that take-back/buy-back operations, possible sending phones to reuse markets overseas, is still a treat to final end-collection – hence, reclaiming control with resources for recycling and recovery. Engaging the public and civil society in the first years is found to be a good investment, not only in trying to pick-up the huge slack of historical mobile phones, but also to establish the system among stakeholders and generally in peoples mind prior to introducing a DRS on all new devices.

As the problem scope indicates, initiatives around EoLM are seen as essential extensions to end-collection, which, opposite, a DRS could ensure. However, to somewhat also ensure technical and technological innovation, initiatives should be taken to ascent EoLM done by OEMs. Initiatives that can ensure increased stakeholder cooperation between e.g. OEMs and the CROs that represent them in different countries, to enable them to establish logistical systems, controlling and guiding the waste flows throughout the recycling and recovery stages. Here, idea of subcontracted the processing of e-waste, establishing resource flows to and from the recycling industry, is found as a solution to ensure valuable asset returns to the OEM – hence preserving information and control with resources inputs for final product manufacture. This approach would naturally create increased network opportunities between OEMs and recyclers, through a B2B setting and expected mutual interest in resource efficiency. From the recycler perspective: To be able to offer competitive recycling services. From the OEMs perspective: To recover as many valuable assets as possible. This is the point of intersection where technological innovation could take place, hence new designs for disassembly and recycling.

Another opportunity for OEMs, prior to final end processing, is found around more establishment or strategic use of service providers for reversed logistics. Here OEMs would be able divide their asset recovery between cannibalizing obsolete products to reclaim spare parts for repair operations or re-manufacturing, additionally to refurbish collected products for reuse. It this sense it should be mentioned that reuse operations on the same market or nearby markets with efficient end-collection systems is vital if the resources shouldn't leave a controlled cycle. Therefore, it seems required that decision makers work around this task to ensure closed loops.

To safeguard against green washing attempts and provide transparency in recycling operations, it is found necessary that intergovernmental decision makers, here preferable the EU, involve with the recycling industry to develop process certification schemes for the production of secondary raw materials (recycled and recovered metal resources from e-waste). This would hereby provide OEMs with an official tool for cycling these resources back into their supply chain, ensuring that such efforts, with a commercial outlook, become truly sustainable in a circular perspective.

Finally it has been found useful to address and engage consumers more directly. As examined in section 5.3.5, a limited selection of OEMs has presently chosen to provide scattered information about the environmental and social profile of their respective product portfolios. Nevertheless, the analysis showed that an almost unanimously amount of people don't receive or feel such information is ever presented to them in the purchase situation. Additionally, a selection of large international MNOs seem eager to establish eco-ratting systems today, to push OEMs into developing more sustainable products and provide consumers with the rightful information that they actually demand of them. However, these eco-ratting systems has yet to include more transparent and equal measures, while also OEMs are not obliged to file product information prior to product commercialisation. It is therefore found necessary to merge these noble efforts for providing consistency. Furthermore, intergovernmental decision makers should engage on this quest so the final outcome of a possible international eco-rating system could obtain full validity and a statutory base. One crucial problem in the present MNO based eco-rating systems was the general low focus on recycled metal content - and so must be ensured in the future. As a minimum, such an estimate must be able be divided into, at least, base, precious and special metals. Both from the perspective of being able to measure progress in the embedded recycled content of ICT products, but also with regards to variations in environmental impact from different metal elements (Appendix 3D). Such an eco-ratting system could therefore provide two-sided information: 1) Detailed product profiles, setting minimum standards, valuable in a competitive setting but also generating useful information for civil society, investors and general public decisions makers. 2) Include simple information, such as a final score on confined set parameters, which consumers is found to require and have easier to navigate from in the purchase situation.

The perspectives in an eco-rating system are thus found to be manifold. While both the RoHS and Eco-design directive have showed to set minimum standards on a global level (cf. section 2.1), similar standards for virgin resource uptake in ICT products are missing today. Technological innovation, especially in the likes of approaching solutions to the entanglement of elements in these high-tech and complex electronic products, probably needs a push from outside the industry. The theoretical discussion set out from section 3.2 also showed a paradox in relying on substitutability in the future contra the thermodynamic challenge that is evident from a metallurgical point of view. There are no obvious challenges to why such an eco-ratting system shouldn't be expandable to other products in the ICT sphere as well as general consumer electronics.

7.2 Comparison of Sustainability Goals and Scenarios Designs

The ten sustainability goals that were finally assembled in section 5.6, has been compared to what the scenarios designs initiate DRS and initiatives around EoLM can provide towards filling each previously identified gap. A qualitative description is submitted in each cell of the two focus areas, starting with ‘*likely’*, ‘*neutral’* or ‘*unlikely*’, which represents the ability to meet the sustainability challenge.

Information Transfer	DRS	EoLM
Enable retailers and CROs to engage and participate in optimizing collections system, so information is shared and transparency is created for the post-commercialisation life cycle without being already lost after the purchase of the product has taken place.	(Likely) a DRS will create a strong foundation for information to be created and preserved in the use phase and on towards the EoL phase.	(Unlikely) initiatives around EoLM can't enable information to be created in the first place and would rely on such coming from e.g. a collection system.
Enable OEMs and their affiliated companies to re establish a closer link with the collection system, ensuring strategic information transfer to the Eol phase.	(Likely) a DRS will enable OEMs to get valuable information from CROs or directly from the system.	(Unlikely) same as above. OEMs would need such information to be establish EoLM operations.
Ensure that recyclers in both the pre- and end processing stages benefit from closer cooperation and information transfer with OEMs or their affiliated companies.	(Unlikely) a DRS cannot ensure this.	(Likely) Initiatives taken around EoLM would indeed ensure a closer network between these stakeholders.
Ensure easy and possible cheap component oriented information for recyclers such as colour codes or universal signs about hazardous parts and resource content.	(Unlikely) Intergovernmnetal regulation or industry standards is needed for this task.	(Neutral) initiatives will not ensure this, but will create an incitament for OEMs and their suppliers to engage in the development of such since B2B realtionships would get established with service providers or recyclers. However, it is likely an intergovernmental regulation task or a matter of industry standardization.

Resources & Value Transfer	DRS	EoLM
Ensure that the products ‘personal value’ to consumers is taken in to account, even after their initial use of the device, establishing the possibility of more controllable, strategically managed, transparent and steady waste flows.	(Likely) it creates a strong foundation for correct disposal, even after a second hand use phase. As long as the product stays in use on the same market, there is a very good chance of end-collection.	(Unlikely) the initiatives that can be taken by OEMs and other stakeholders in the EoL phase cannot address a problem that is mainly located in the use phase.
Ensure that the shipment of collected devices as ‘re-use’ to markets overseas will be seen as less of an option, despite confusion of costs and benefits to recipient countries and their citizens, since this has uncontrollable consequences. Establishing a foundation for end-collection and thus a closed cycle.	(Neutral) a DRS setup could be combined with organisational requirements for recycling and recovery operations to take place inside the union. The problem of securing sensitive data would no matter what require total data destruction either through recycling or reversed logistics operations. However, the WEEE-directive still enacts the possibility of preparing collected devices for reuse on foreign markets, becoming a policy issue.	(Neutral) initiatives can not prevent the shipment of functional devices to reuse markets overseas, but with the right process certifaction procedures and transperency of operations, it will maybe not make overall sense for at least OEMs to do so.
Ensure metal resources can be kept in the value chain, transfering from recycling and recovery to product manufacturing; creating more efficient and beneficial resource flows. As a result stakeholders in the value chain can rely on less dynamic resource costs, thus finally more viable commodity prices.	(Neutral) a DRS can ensure metal resource gets to the EoL phase, but cannot ensure that they finally become parts in new ICT products. However, it would likely benefit both OEMs and stakeholders in the recycling industry due to greater resource and value transfer from much better overall collection.	(Likely) metal resources would have a good chance to be efficiently recovered and also become part in new ICT products. It is found very likely that such initiatives can benefit stakeholders throughout the EoL phase and on to the supply chain for new product manufacture.
Ensure the creation of strategic recycling and resource recovery operations, where OEMs and their CRO representative can help to guide waste flows into the right metallurgical routes and recyclers can specialize and optimize processes from more homogenous waste fractions.	(Neutral) it only enables OEMs to work with CROs to manage and transfer the collected resources to recyclers in the industry. However, it creates indirect incentives to make more strategic resource recovery out of the collected products.	(Likely) appropriate EoLM operations can indeed ensure more strategic waste treatment systems, since it is the main point behind it.

Technological Innovation:	DRS	EoLM
Ensure *Design for Environment & Sustainability* . Aiming to reduce the complex mix and number of elements in ICT products, to meet the metalurgical recovery challenge. Create an opening to future design possibilities of e.g. biodegradable compounds and soluble substrates, as ways to create ever more fine metal fractions.	(Unlikely) It will only create a good foundation for resouces to stay in cycles. It must be integrated on a European level to create an indirect effect on OEMs design strategies. Adoption of eco-innovative DfES operations is thus seen as an additional to DRS's.	(Neutral) If all initiatives are taken, it is likely that the result of such would aspire to eco-innovative changes in product designs. However, it seemingly also very much depend on the establishment of large and detailed flows of obsolete products from end-collection.
Ensure *Design for Disassembly*. Ensuring easy component/resource liberation and a way to meet more efficient recycling and recovery operations.	(Neutral) same as above. However, if DRS gets broadly adopted in Europe there is a good chance that OEMs would see DfD as a way to dissassembly main components easier from a larger inflow of obsolete products.	(Likely) if all initiatives are taken, OEMs would very likely see it as way to approach better recycling and recovery rates from more homogenous waste fraction of obsolete products.

7.3 The Path to Sustainability

It is finally sought to evaluate and how the possible initiatives compliment the vision and objectives as first defined in section 4.2 and viewed underneath:

Create permanent incentives for continues technological development in product design evolving the sustainability profile on each product through eco-innovations that ultimately can meet full recovery of metals in the long term. In this light, it is outmost crucial to facilitate and secure information transfers in the post commercialization phase of a product life, to ensure full control of resources and retain value all the way back to the supply side of manufacturing operations. By seeking abundance in secondary raw materials production of metals and creating symbiotic relationships with stakeholders in the post-commercialisation phase of product life cycles, to confine and eliminate losses of resources fixed in obsolete products, and to finally close the metal loops.

Closing the metal loops around ICT products depend on a large set of variables to meet the benchmark of the future. On the positive side, very few obstacles have been identified to prevent decision makers from taking valuable action today.

Therefore, it is very likely, given that both DRS and initiatives for EoLM is established, that it would create sufficient information, resource and value transfers to the EoL phase as well as ensure recycling and recovery operations that ultimately can lead metals back into the supply chain. This also means that incentives for incremental technical and technological product design and innovation would be permanent. Nonetheless, it is still found necessary to address the issue of collected devices going to reuse markets overseas, which can't be fully avoided in the current regulation regime. It is thus an issue that decision makers must address and integrate into future policy.

In a geographical perspective and especially for having a chance of pushing technological innovation in the right direction, it would be necessary to see efficient end-collection systems be integrated all across Europe. It is unlikely that a single DRS, even if established in a couple of member states, would have any significant effect on OEMs, pushing them to make eco-innovative designs. Nevertheless, a single DRS will, to a high certainty, ensure higher collection rates in the member state that chooses to carry it out. Where initiatives to establish a good eco-ratting system or ensure process certification of end-processing operations, possibly would be in the range of a few years to establish, DRS has a bit longer time horizon. However, the ten-year perspective that was initially put forward seems sufficient to establish and experience desirable change.

In light of this analysis a couple of recommendations to approach a sustainable path in the future, can finally now be assembled. It would be somewhat valuable to initiate a DRS in a single or a couple of member states, through the two-step model, by first; addressing collection of historical phones, while secondly working towards full system introduction. A single DRS could become a valuable pilot and thus establish a practical experience base for others to follow. Secondly, there is already found significant attempts to establish eco-ratting systems that can be seen as an essential foundation for measuring circular and sustainable progress in the ICT industry and in the future. Merging efforts or embracing this progress from an intergovernmental point of view, would maybe be able to open up the ICT industry, which seemingly has a closed nature around issued external effects of corporate operations. Lastly, initiating process certification of recycling and recovery of metals in end processing would create a foundation for ensuring sustainability and transparency - circling recovered metals back into the supply chain and also to let OEMs use their initiative in commercial sense.

8. Conclusion

A final conclusion has been assembled to answer the *problem formulation*, as viewed here:

> *'How can new system initiatives for DRS and EoLM be designed and applied to the post-commercialisation life cycle around ICT products, contributing to a circular and sustainable production and consumption system, assessed through mobile phones, to approach full recycling and recovery of finite metal resources?'*

Through designing a scenario of a national DRS for mobile phones in Denmark, it was found most efficient to see such system in a public and private manner, where collection points could be established in both relevant retail stores and the existing collection sites. By introducing a DRS in two steps, it would be possible to address the issue of collecting historical devices and at the same time, building a mental foundation prior to full system introduction. The scenario showed a solid foundation for establishing such a system, with regards to the socio-economic benefits and for possibly achieving very high collection rates. Funds for start-up and running system costs can be achieved through unredeemed deposits and the metal resource revenues from collected devices. The consumers largely acknowledge a positive value towards such as system. However, here it was clear that most consumers attached strong personal value to their old mobile phones, while they simultaneously needed a strong monetary incentive for correct disposal. This meant that a deposit size approaching 200 DKK (around 25 EUR) is found needed to achieve high collection rates in the future. Finally, a DRS was found very likely to create detailed collection information that could be used by OEMs to guide products and components to efficient recycling. By attaching the deposit to the phone itself, using the embedded IMEI data, it would also become possible to let it travel around in society, on the second hand market, and still recover it in end-collection.

To finally close the metal cycles and approach sustainable recovery, OEMs will need to be further engaged with a collection system, like a DRS, reclaiming spare parts for repairs and possibly remanufacturing, or refurbish devices for reuse by using service providers of reversed logistics. For direct recycling, OEMs could use the opportunity to sub-contract the e-waste to end processors, and so being able to keep ownership of the metals. This would enable OEMs to strategize and secure recovered metals to its supply chain, while bypassing possible distortions and dynamics on the metal markets and serious environmental and social concerns of primary production. To secure and make transparent metal resource flows from recovered ICT products, which could possibly be used later in a commercial sense, certification of processing operations was found needed. This certification should be developed and founded in an official order. It is also found necessary to further develop existing or new eco-rating systems for ICT products, which addresses the information gap consumers experience in the purchase situation. Such an eco-rating system could compliment information transfer back to the public and let OEMs use their closed loop and sustainable achievements in a good manner. Here it would be possible to measure progress in the industry and possibly push OEMs to achieve even better results in the future. If the above mentioned EoL progress is initiated it is thus found more likely that OEMs would also choose to approach more eco-innovative product designs in the future.

However, it is found unlikely that OEMs would make larger changes on needed product designs and engage in EoLM operations if efficient collection was only founded in a single or few national settings. Here OEMs needs sufficient and detailed resource inputs. Therefore, to see more extensive progress being made, it would be necessary to make DRS's broadly adopted throughout the EU. Another problem is that there is no guarantee that private stakeholders would not choose to ship functional devices for reuse overseas and so control of the resource would be lost. Therefore, to prevent this it would mean that either corporate or public policy had to be altered around securing reuse products on national or nearby markets.

8.1 Afterword

In light of this analysis, it is found appropriate to share some considerations for and behind the study. With this analysis it was intended to find and show where and possibly how more sustainable production and consumption patterns could be initiated and carried out in the future. It is thus believed that the more consolidating nature of this normative approach has brought about a good visualizing starting point from where stakeholders, in and around the ICT industry and public authorities, can start to develop the policy for circular system designs.

The study of electronics and ICT products in their socio-technical and institutionalised setting is packed with both opportunities and several constraints. The technological development is fast and somehow a precondition for the industry and the societal setting it both influence and is founded on. This both give vast opportunities for innovation into better product designs, but also may limit the focus in the industry to just focusing on next years model of a given device. Here, *product service systems* (PSS), such as leasing, was actually investigated and included into the empirical analysis, but was finally removed from the study scope due to time constraints and to limit the extend of the analysis. However, both the consumer survey and several business cases showed that there could be a good foundation for looking into e.g leasing models for ICT products. It could thus be interesting to go further into researching the opportunities in more control based and shared business models, where the OEM or retailer becomes much more involved in to the use and end-of-life phase, than they seemingly are today. Here, there is possibly a good opportunity to recover resources and value by building stronger business to consumer relationships.

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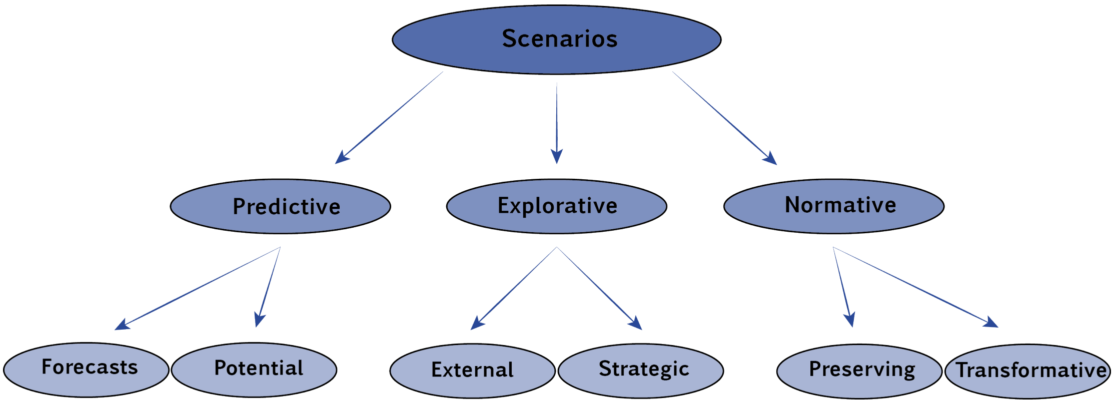
Appendix I: Methodological Descriptions

1A. Different Approaches to Scenario Analysis

Höjer et al. (2008) has collected and evaluated descriptive classifications of the different scenario approaches in relation to various environmental system analysis tools. The three categories range from, *predictive*, *explorative* to *normative*. According to Höjer et al. this generates six different approaches. The typology was original developed in a previous study by Börjeson et al. 2006.



'Scenario Typology'. Remade illustration, originally presented in (Höjer et al. 2008: 1959 + Börjeson et al., 2006).

Predictive Scenarios: Is characterized by *forecasting* measures on future impacts (e.g. what will happen), or creating *potential* scenarios (what if this happened) both in correlation with data of analysis e.g. statistical growth indicators. Where forecast (FC) scenarios picture the most likely result, potential scenarios embed special conditions to answer to a specific decision or possible event. Predictive Scenarios are in most cases made up by external factors that are uncontrollable by the decision makers. In relation to this report this could be a market or extraction trend of metal and mineral resources globally. The exogenous nature of predictive scenarios makes it most suitable for short-term perspectives (Höjer et al. 2008: 1960).

Explorative Scenarios: Derives from scenarios corresponding to different potential future developments, normally with a longer perspective. The study differs from being external or strategic. In the first option (external) it may be relevant to look for how different external factors would have an impact over time and, or, in combination (e.g. forecasting resource extraction vs. know reserves etc.). In the second approach, a strategic study would aim to describe different consequences of strategic decisions over time (if we act in this way, what would happen in the long term). These studies typically apply in policy action scenarios. A combination of the two approaches is often seen as a way to explore and make robust position on different action scenarios based on the present (ibid.).

Normative Scenarios: Takes a starting point in one or various demarcated and well-defined goals. The question to answer is, *"How could we reach that target"*. The preserving approach goes on and seeks to find how the target is met within the current conditions. The transformative approach, on the other hand, embeds a highly valued future target. The target can seem unreachable due to present predictive scenarios, but the question here is to identify the prevailing blocking structures that are to be changed. Backcasting scenarios are seen as a transformative approach, but as the targets also need to be clarified, backcasting scenarios sometimes depend on forecast studies to identify barriers, systems and prevailing structures. Transformative studies are most often conducted in a long-term perspective (ibid. + 1961).

1B. Backcasting

The relative simplistic theoretical foundation of backcasting has been discussed earlier in its development (Dreborg, 1996: 814), but if we simply think of backcasting as a technique to drive innovation strategies and systematic reveal the path we actually need, the questions of todays e.g. technological capabilities become more or less obsolete. From a broad range of studies Karl H. Dreborg derived five parameters where backcasting should be considered:

- When the problem to be studied is complex, affecting many sectors and levels of society;
- When there is a need for major change, i.e. when marginal changes within the prevailing order will not be sufficient;
- When dominant trends are part of the problem-these trends are often the cornerstones of forecasts;
- When the problem to a great extent is a matter of externalities, which the market cannot treat satisfactorily;
- When the time horizon is long enough to allow considerable scope for deliberate choice.

(Dreborg, 1996: 816) (Holmberg & Robért, 2000: 294)

In correlation with these ‘checkpoints’, the subject area has reflected a solid base for the use of backcasting as an approach for this analysis. Electronics today has very complex value chains, creating externalities through most of the lifecycle. Moreover, small changes (e.g. incremental improvement to energy efficiency) and linear economic trends (ultimately creating waste flows of finite resources) was found insufficient to solve the problems in a long-term perspective. Therefore, applying a backcasting approach to look for system paths, that could lead the way towards sustainability, was ultimately found relevant for this methodological course.

Backcasting by J.B. Robinson

Robinsons has developed his formal backcasting methodology, as a way to integrate natural considerations in human system scenarios, which is more thoroughly described in his article ‘Future Under Glass’ (1990). The overall approach is outlined as seen below:

1) Determine Objectives:
(a) Describe purpose of analysis
(b) Determine temporal, spatial and substantive scope of analysis
(c) Decide number and type of scenarios

2) Specify Goals, Constrains and Targets
(a) Set goals, constraints and targets for scenario analysis
(b) Set goals, constraints and targets for exogenous variables

3) Describe Present System
(a) Outline physical consumption and production processes

4) Describe Exogenus Variables
(a) Develop description of exogenous variables
(b) Specify external inputs to scenario analysis

5) Undertake Scenario Analysis.
(a) Choose scenario generation approach
(b) Analyze future consumption and production processes at the end-point and mid-points
(c) Develop scenario(s)
(d) Iterate as required to achieve internal consistency

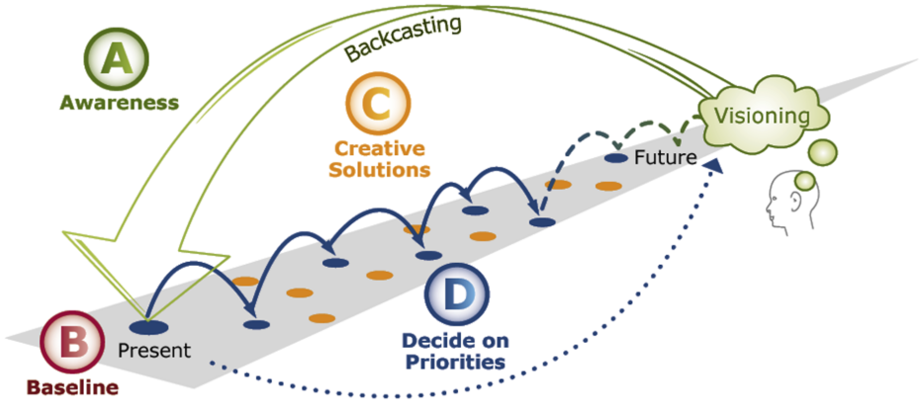
6) Undertake Impact Analysis.
(a) Consolidate scenario results
(b) Analyze social, economic and environmental impacts
(c) Compare results of step 6(a) and 6(b) with step 2
(d) Iterate analysis (steps 2, 4 and 5) as required to ensure consistency between goals and results

Determine Implementation Requirements (With step 1)

Adopted from the outline originally presented in J.B. Robinson (1990: 824f)

Backcasting by K.H. Robèrt (The Natural Step International)

ABCD-analysis developed by K.H Robèrt (2000: 247) consists of 4 overall steps. Robèrt, being the founder of The Natural Step, has been implemented the model in the organisations work. As pictured in the figure:



'*Applying the ABCD Method'*. Illustration reprinted, courtesy of The Natural Step International, 2013 (CC). The figure visualises, in a simplified manner, how to apply backcasting to e.g. an organisations search for strategic choices. In this way they encourage organisations to use the method as a tool for setting op goals and pave the way - to walk on the right path towards a shared vision.

A) Awareness and Visioning: First, the establishment of a shared mental model and vision of a "whole system" and success – system characteristics, principles of success (e.g. sustainability), and strategic guidelines. **B) Baseline Mapping:** Second step is to move back and examining the current reality through the lens of the preset of principles *(i.e. identifying violations of each principle and current assets to address the challenges)* by conducting a baseline assessment or a "sustainability gap" analysis. This could for instance be on systems, products and services, and on the economic, social and environmental impact. Making the researcher or group capable of finding opportunities for change. **C) Creative Solutions** Thirdly, the goal is to design solution scenarios for change. Going from the vision of success (A) and with the knowledge of (B), the researcher or group can now take on the development of scenario strategies towards the vision – in this case, principles of sustainability. Solution scenarios can be manifold, since they will be further qualified in the final step. **D) Decide and Prioritise** Fourthly, strategic selection and prioritisation of initiatives or solutions found in step (C). The researcher or group should now pursue to select short-term "low hanging fruits" and establish the foundation for long-term progress along the sustainability principles, towards the vision. Finally, assess decisions by evaluating with step (A). *This description was developed and based on outlines by* Robèrt (2000: 247), The Natural Step (2013: c) and Waldron et al. (2008: 13). The ABCD-model is seen as a strategic tool and a way to use backcasting in a formalized way – for instance in organisational planning processes.

Appendix II: Technical & Technological Aspects

2A. Technological Innovation for Future ICT Products

Going a step further and into the products themselves, some development and innovations features are found very relevant today. The overall questions on substitution possibilities and resource recovery might partly be found in technological progress. What is searched for here, is if there is evidence for technological progress that can add capabilities of recycling more metal resources in the future, given that socio-technical systems around ICT products were to nourish such innovations. In this case, there are many positive indicators for actual scientific progress in alternative materials development, which could promise actual easy recoverability of metals from product components.

Organic or plastic electronics seem to be the new hot area of interest for substituting elements (where 'organic' means carbon based materials) though not necessarily fully eradicating the need of the conductive metals just yet. However, making it easier to recycle and recover metals is the considerable advance here.

Plastic electronics is an emerging field of science and has made remarkable advancements lately. However, biodegradability is often not considered, and currently most advancement has come from synthetic pathways (Irimia-Vladu, et al., 2012: 341). The most mature technology such as *organic light emitting diodes* (OLED) has already been packed in to millions of Samsung devices such as smartphones. Recently major progress has also been made with *organic photovoltaics* (OPVs - organic solar cells) reported to have significant higher power conversion efficiencies of above 10% in in 2012. Another field is also emerging for organic field effect transistors (OFETs). OFETs could replace the use of the normal metal-oxide semiconductor field-effect transistors (MOSFETs) in the future - used for e.g. displays and microchips (ibid.).

While some organic solar cells are still being based on petrochemicals, synthesized substrates with a feedstock of e.g. wood and paper could make it both biodegradable and as renewable parts of solar cells (Zhou, et al. 2013: 1). Why the question is simply maybe more a matter of when and how to adopt this to other parts of electronics sphere, like in ICT products. In a recent study, organic solar cells are placed on cellulose based nano-crystal substrates, which enables the recycling at room temperature by simply immersing the cell in water, where the substrate is dispersed. This makes it possible and easy to separate out the rest of the components; the polymer solar cell and the metals (Zhou, et al. 2013: 2).

Substrates and insulators generally have more environmentally conscious facets, where these could be made not only into biodegradable compounds for use in electronics but also made to be non-toxic. Paper (cellulose) has shown to be an excellent substrate for electronics, providing both flexibility and inexpensive material. Silk, gelatine, along albumin from egg whites are other very known protein based materials, which also have been shown to have good insulating properties (Irimia-Vladu, et al., 2012: 341). Polysaccharides (of carbohydrates) such as starch (amylum) can be extracted in large amounts from food wastes (e.g. from potatoes, rice, corn, wheat, casaba and so forth), and combined with polylactic acids to make polymers (this has been commercially done by e.g. BASF). Another well-known polymer is shellac, which together with silk has been demonstrated to make smooth surfaces when made in to thin films, and can go in printed electronics (ibid. pp. 342f).

For semi-conductive materials, textile dyes represent good capabilities, where *Indigo* and it derivatives could be used instead. Though it is synthetically produced today, it originates from several plants and has been extracted since ancient times – once being a very valuable commodity. Using a single contact electrode of gold and evaporated to polyethylene passive aluminium-oxide dielectric, it has shown to have impressive semi-conductive properties (ibid. pp. 343f). For non-metallic conductors, melanin and chitosan biopolymers have been demonstrated to also have useful properties (ibid. pp. 344ff). Nevertheless, biodegradable electronic consumer devices are still in their research infancy at present (ibid. p. 346), where the above-mentioned possibilities just show the material capabilities, within their natural origin, that could be valuable in future applications.

Nevertheless, printed, organic and flexible electronics are altogether growing markets and an expected part of the future of electronics. In IDTechEX's latest forecast they expected the market to increase from 16 billion USD this year, 2013, to around 77 billion USD in 2023, largely led by OLED displays and secondly by conductive inks and solar cells (PV) (IDtechEX, 2013:a). The conductive inks are usually based on silver, copper or even gold and offer new opportunities for making very thin and resource efficient electronics, where the inks can be used to print e.g. circuits on various substrates (IDTechEX, 2013:b).

Therefore, it seems there are many opportunities for organic and inorganic materials to merge in the future, while biodegradable materials may have a possible opportunity to be embedded in new components and substrates that can help relief tiny metal parts to be sorted out and recycled. If sufficient initiatives are taken to transform the socio-technical systems around ICT products, such innovations might be useful tools to meet further recoverability of metals and thus create more sustainable waste flows.

2B. Typical and Main Components in ICT products

- **Casing:** Encases the electronics components and holds things in place. These are made of a variety of metals and plastics.
- **Screen:** Flat panel displays (FPDs) and electronic visual displays (EVDs or touch displays) – yes, they have many names. But, screens are often just called LCDs (liquid crystal displays), because this is the basic technology in most of them. LCDs need backlighting and the newest screen technologies use light emitting diodes (LEDs) where OLED and AMOLED are recent organic/plastic versions of this technology.
- **Hard Disk Drive (HDD)**: For data storage made on spinning magnetic platters. New data storage components are made with flash memory technology, also called solid-state drives (SDD), using semi-conductor chips. Small flash memory chips are used in portable devices such as smartphones, cameras and tablets.
- **Battery**:** In portable devices batteries are usually of the lithium-ion (Li-ion) type or sometimes nickel–metal hydride (NiMH). Newer devices also embed lithium-polymer batteries.
- **Printed Circuit Board (PCB):** A plastic board that holds and wires the entire electronic miniature world together. The electronic circuit routes the transistors, resistors and capacitors together. Microprocessors or microchips are soldered on to the board in small plastic or ceramic enclosed packages, containing microscopic integrated circuits with millions of transistors made of semi-conducting metals (commonly of silicon/gallium).
- **Wire:** metal wiring covered in plastic insulators.
- **Antennas:** For transmitting and sending analog/digital information in mobile phones and other devices such as tablets.
- **Microphone*:** Usually of the type electret with permanent magnet, which is used in most ICT devices.
- **Speaker:** Containing permanent magnets.
- **Keyboard:** E.g. for desktop and notebook computers
- **Camera:** Built with semi-conductor metals, turning the analogue light signal into digital information.
- **Cooling elements and fans:** in desktop computers and notebooks.

Sources: 'UK Environmental Agency (2011: section 6.9'), (HowStuffWorks.com), Öko-institut (2012: 19-28), *BeStarTech (2013) **, UNEP (2013: 228).

2C. A Selection of Base Metal in ICT

Base Metals	**Properties and Use in ICT**
Co	Cobalt is mainly used and is an important element in rechargeable batteries for consumer electronics. In Lithium-ion batteries, which are by far the most common battery type in ICT today, cobalt account for approximately 50% of the cathode weight (Cobalt Development Institute, 2006: 48). An estimated 25% of global cobalt production is used in the electronics industry (Young, 2011: 2).
Cu	Copper is widely known to be used in wires. Due to its high conductivity (only second to silver), ductility, malleability and resistance to corrosion it is the third most used industrial metal after aluminium and iron (EC, Annex V, 2010: 55). Copper provides the basic circuitry, wiring and contacts for computers, TVs and mobile phones etc. Copper is also another main part of rechargeable batteries. (Copperinfo, 2013)(UNEP, 2013: 217).
Sn	Tin has a low melting point, does not corrode easily and is extensively used as a solder for contacts in electronic circuits and wiring, where it is frequently mixed with a little silver to give higher conductive properties. Tin is also used with indium to make indium-tin-oxide (ITO) for LCD screens (UNEP, 2013: 214). In the mid 2000s 29% of global tin production was used in the electrical and electronics industry (UNEP, 2011: 29). A more recent estimate says 35% of global production goes to the electronic industry, which might be explained by the growth in ICT electronics, for example (Young, 2011: 2).
Zn	Zinc has strong anticorrosive properties, which makes it ideal to use as an alloy together with Cu and other elements (Geology, 2013 [b]). It is used in various forms in PCBs, batteries and as a phosphor emitter (UNEP, 2013: 215+217). Zinc oxides is being investigated for replacement of the more expensive indium-tin-oxide, which is preferred today (ScienceDaily, 2012)

2D. Precious Metals in ICT

Precious Metals	Properties and Use in ICT
Au	Gold has remarkable properties and thus its high cost is justified by its reliability. It is practically indestructible, resistant to tarnish, making it completely recyclable and it is immune to air, water and oxygen. This is why it is used to plate and coat against corrosion in dry circuits. Au also has a high conductive property and is therefore used in computers and telecommunications equipment such as mobile phones, for connectors, switch and relay contacts, soldered joints, connecting wires and strips. Though, it has superior properties it is also soft, ductile and pliable, making it more applicable as a contact material to low current and voltage products such as ICT and televisions (to avoid melt off). The needed data transfer in ICT circuits makes Au a favourable element as an effective and reliable conductor of electronic information between components. Therefore, Au is almost always used to mount e.g. microprocessors and memory chips.
Ag	Silver has the highest conductivity of any element, but its greater cost than copper has averted it from being as widely used in electronics. But its use in electronic products is due to its superior conductivity, and because it has the highest thermal conductivity and the lowest contact resistance of any metal. PCBs are made using silver paint and it is used to make super alloys due its conductive property, which is why it is also mixed with tin in solders.
PGMs - Pt, Pd, Ir, Rh, Ru and Os	PGMs have some of the same properties as Au and Ag, but are generally harder, denser and have higher melting points. They posses high conductivity, durability, temperature stability and are resistant to oxidation. They are very rare elements and thereby also costly. Due to their unique properties they are used to make capacitors in e.g. computers and mobile phones, where energy is stored in an electrostatic field. For instance Pt and Pd are used for coating the multi-layered ceramic capacitors. Pt, Pd, Rh and Ir are also used to coat electrodes, establishing the contact between non-metallic parts of circuit to control the flow of current. Ru is used for data storage components in HDDs and also in resistors (approx. 80% of global production). Os is rarely but sometimes used as a substitute for Au plating.

Sources: (Swanson, 2006) (Geology, 2013 [a]) (IPA, 2013) (UK Environmental Agency, 2011: 74-78)

2E. A Selection of Special Metals in ICT

Special Metals	Properties and Use	Sources
Be	**Beryllium** besides being very toxic, it is both a very light and very strong element, which is mostly used in very low quantities as an alloy with Al and Cu. Used in PCBs and in spring functions such as keyboards and computer printers.	1, 6, 7
Ga	**Gallium** is a semi-conductor and is extensively used in the industry to make everything from LEDs to transistors. 95% of global demand goes to these components along with some optoelectronics. Therefore, It is widely used in portable devices such as mobile- and smartphones.	1, 6, 7, 8
Ge	**Germanium** is a semi-conductor metal used to make high-speed integrated circuits (microprocessors). It is beginning to substitute Ga due to lower costs. It is also doped with small amounts of In, Ga, Sb in the making of LEDs.	1, 7, 8
Hf	**Hafnium** is used to make high-efficient electrical gate insulators in the semi-conductor industry e.g. for transistors and displays. Sometimes substituting Si in microprocessors.	1, 5, 7
In	**Indium** is very important in the making of screens and displays (LCDs). Indium is used as indium-tin-oxide (ITO) to make the unique combination of electrical conductivity and optical transparency. Crucial to the making of touch displays in smartphones and tablets. It is also used as a doping agent to make transistors.	1, 5, 6, 7, 8
Li	The lightest metal of all is **Lithium**, which has a strong ionic character and is the most popular element to make rechargeable batteries such as lithium-ion and lithium-polymer for laptop computers, mobile phones and tablets.	1, 7, 8
Nb	**Niobium** has similar properties to Tantalum, to make the crucial high efficient capacitors, thus it has been used to substitute Ta when prices where high.	1, 7, 8
Sb	**Antimony** as a semi-conductor it is used in the industry as a dopant for Si wafers.	6, 7
Ta	**Tantalum** is a very important metal used to make capacitors fundamental to all electronics. Its superior ability to store electrical charge due to its dielectric constant has had an impact on the miniaturization of electronics and it is used in all handsets and portable devices such as mobile phones and laptops. 60% of global production or more is used in the electronics industry – especially in ICT products where it is a key element to the production of billions of smartphones	1, 3, 7, 8

	and tablets.	
W	**Tungsten** is a very important element in integrated circuits, where it helps remove heat from microprocessors, as plugs and pins on the chip. It is both applied as pure W and as an alloy with titanium in thin films. The miniaturization of electronics again plays an important part as W act as a heats sink, removing it from high-energy centres on the PCB. 35% of global production goes to the electronics industry.	2, 3, 6, 7, 8
REEs - Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu	These 17 so-called rare earth elements (**REE**) are vital to the electronics industry and especially in the miniaturization of electronics, which foremost include ICT. Some are very rare others like Cerium are regarded as very abundant. Therefore the definition of 'rare' is relative since it is linked to the commercial exploitation and extraction of them, where China stands for 95-97% of global production. They are usually associated with the production of light and strong permanent magnets, from alloys with other metals and some have distinctive optical properties. Utilizing their unique abilities, often together or with other metals, they are often applied in very small quantities per product. Neodymium is the most common element in the making of permanent magnets, and when mixed with B and Fe they can become12 times stronger, compared by weight with conventional Fe magnets. This is used in all ICT to make in-ear headphones, microphones, speakers and HDDs. Other REEs for high intensity magnets in electronics and audio equipment incl. Sm, Dy, Pr, Tb. Other uses; for optical ultra fine polishing (Ce), and optical additives in lenses and displays; Ce, La, Nd. Rechargeable batteries are often made with Lanthanum alloys. In displays and screens a number of elements are used as phosphors to produce and manipulate different colours; (Y, Er, Tb, Gd, Ce). In summation, the REE elements contain unique physical, chemical, nuclear catalytic, electrical, magnetic and optical characteristics, which are widely used in ICT.	1, 4, 5, 7, 8

Sources: (1) Avalon Rare Metals Inc. 2013, (2) ITIA, 2003, (3) Young & Dias, 2011, (4) Massari & Ruberti, 2012: 41, (5) NewElectronics, 2013, (6) UK Environmental Agency, 2011: 74-78. (7) UNEP, 2013: 216-18+220-222. (8) Öko-institut, 2012: 30+37-39.

2F. ICT development

According to N.K. Hanna, we are in the midst of a so-called ICT revolution, meaning that we are at an early stage of long-term societal integration of ICT technology. "*Promising paradigm shifts within computing and communication point to a continuing dramatic decline in prices and increase in performance and intelligence of ICT systems*" (Hanna, 2010: 27). This and more, is what is promised with our transformation into a mature information society. Social and business policies to harness and adopt this *'revolution'* are also being implemented all around the world. In the EU the policy is called "Digital Agenda for Europe". This flagship program contains 13 achievement points, which should lead to physical, economical and social development of the ICT infrastructure towards 2020. This includes vast broadband integration, e-commerce, e-Government services, acceleration of cloud computing and increased R&D investment budgets. The annual progress is evaluated in a scoreboard report (EC, 2012 [a]).

Mobile and portable devices are the future of this development and the indicator for Denmark's and the EU27's digital status in 2011. The indications include the Danish mobile take-up penetration of 152 active SIM cards per 100 people compared to 130 for the EU27 on average, and 65% of all Danish companies provided portable devices to their employees, compared to a 48% EU27 average (EC, (2012) [c]). According to Danish household possession statistics of various electronic appliances and devices, landline telephones are phased out (down to 50% possession in 2013) and at the same time almost everyone possesses a mobile phone (98%), where recent numbers shows that currently 63% of Danes possess smartphones in 2013. The development of the new tablet and mini-computer market has increased possession to 33% in approx. 3 years (DST, 2013 [a]). These Danish figures are very similar to the rest of Western Europe and the US.

On the global scale, the ICT market is growing - about 5,1% to 2.57tn EUR world-wide in 2012, driven by emerging markets with approx. a 27% share of global ICT procurement. In 2020, emerging markets are expected to be 50% of global ICT sales. Western Europe recently had the lowest growth rate of only 1,2% (EITO, 2012). This means two things, that growth in ICT sales will happen mainly outside mature markets since these markets seems more or less saturated. Therefore, reasons for extensive counter policies around e-waste in emerging markets could seem to be evident for the future, but the Western European market is still almost 3 times greater than e.g. the Chinese market (respectively 617 and 220m EUR) (ibid.).

2G. The ICT Paradigm

Charles Eisenstein extensively points out in his work *"the Ascent of Humanity",* that we, as a society, are addicted to the "technological fix" and that our belief in science (as a means to provide all the solutions) prevails over time and history, also as an attempt to control nature (Eisenstein, 2007: 5+15+17ff). This can be problematic, because if we always hope for a "technological fix" we may forget to fix the flaws in the socio-technical systems.

Popular descriptions like "cloud computing", "big data", "mobile", "smart devices" "smart cities" are everywhere and only point in the same, one direction – *the Internet of things*[85]. According to a recent survey done by SAP and Harris Interactive, 'the Internet of Things' is where machines talk to other machines (also sometimes referred as M2M) through connected sensors and devices. The three pillars of this development are seen as "mobile devices", "big data" and "cloud computing". As far as this study goes, mobile devices will outnumber people on the planet in 2013 and increase more than threefold to 24 billion devices by 2020. This year it is expected that a staggering 4 billion terabytes of data will be stored and that over 90% of all devices will have access to personal data cloud services (SAP & Harris, April 2013). Misuraca explains that, as broadband Internet spreads across Europe, technological progress will lead to smaller and smaller products and portability will be pervasive. As mobile devices become more and more important, it could possibly lead to ambient intelligence and ubiquitous computing. At the same time, technology trends are expected to develop faster than society and organizations can keep up with, challenging the way in which large amounts of newly created data is handled (Misuraca & Wainer, 2010: 22). Nevertheless, before celebrating our ingenuity and design capabilities; it is necessary to critically reflect upon these issues.

In this regard, strategist in international ICT development Dr. Nagy K. Hanna has explored the implication of this new industrial paradigm. Whereas the first industrial revolution was driven by the invention of the *steam engine* and the second by the *electric generator,* ICT is seen to be the driver of the present industrial revolution (Hanna, 2010: 30). These technologies are all three characterised by being general-purpose technologies, meaning that they possess: "*(i) a wide scope for improvement and elaboration; (ii) applicability across a broad range of uses; (iii) potential for use in a wide variety of products and processes; and (iv) strong complementarities with existing or potential new technologies"* (ibid.). As Hanna explains, even though the historic technologies revolutionized industry with the increase in productivity (short-term gains), the long-term impacts will be profound and have typically been underestimated (ibid.).

With this in mind, this so-called revolution where 'things' can communicate and information is widely shared, might promise a revolution in everything from; energy-efficiency, education, health, poverty reduction, urban development, innovation, media and culture development, but it might also include pervasive and negative impacts.

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[85] A simple Google search on "The Internet of Things" generates roughly 1.9 billion hits.

Hanna also refers to a new techno-economic paradigm, which everyone subscribes to by accepting the means for modernizing all existing industries, activities and infrastructures (Hanna, 2010: 30).

> "It represents the most effective way of applying a particular technological revolution and of using this revolution for transforming a whole economy. When broadly accepted and adopted, these principles or generic tools become the common sense basis for innovation and investment, for organizing activities, and for structuring institutions. A techno-economic paradigm gradually defines the new best-practice frontier" (Hanna, 2010: 31)

In this context, it is very likely that the technological trends seen today and the way ICT has become a growing part of everyday life for many people, will determine not only societal development but also it's pervasive impact on nature. In the light of this study, and without disregarding other possible negative effects (that Hanna also cautiously examines), these impacts are likely to take the form as pollution and waste of resources – at least if they are not initialized carefully. The possible impact from 'creating' 24 billion new connected devices in 2020 as mentioned previously, seems to be a merited indicator for an immense drain on natural resources. Therefore, on the way to connecting everything through *the internet of things*, we may actually discard double or triple that amount, since the current life span of ICT products range in the area of "2-3 years" (Robinson, B.H., 2009: 184).

2H. Recovery Definitions

Repair	Original product used after fixing or replacing broken or faulty parts.
Refurbishment	Original product quality restored after disassembly to a certain level and repairing/replacing the faulty or broken components/parts.
Remanufacturng	'New' product is manufactured from old (recovered from disassembly of old devices) and new components. Technological (software) upgrading may also be carried out.
Cannibalization	Reusable parts and modules are recovered from used products, to be used in any of the three operations mentioned above. Others are scraped.
Recycling	Materials recovered from used products and parts by vigorous separation processes (without conserving any product structure).
Energy recovery	High calorific value components (e.g. plastics) could be incinerated in modern waste-to-energy plants for electricity generation or in smelters and cement kilns as source of energy.

Definitions Obtained from Nnorom & Osibanjo (2010: 331)

2I. Design for X (DfX)

'Design for X' is a set of attributes or parameters that the manufacturer can choose to strategically embed in the design order for a product line. DfX should be seen in the context in which a product is defined – its main utility, its functions, its properties, its cost and aesthetics. The list can be long and modern designers often have to consider various attributes that ultimately can determine its success or failure. This is arranged under this design paradigm, where the X can be any number of design values (Graedel & Allenby, 2010: 118f). This list include among others, *Design for*:

"Assembly (A), Compliance (C), Disassembly (D), Environment & Sustainability (ES), Manufacturability (M), Material Logistics and Component Applicability (MC), Reliability (R), Safety and Liability Prevention (SL), Servicability (S) and Testability (T)" (Graedel & Allenby, 2010: 119f).

While these parameters are connected by default, the important issues in the analysis have been Design for "Disassembly" (DfD) and Design for Environment and Sustainability (DfES). Descriptions underneath:

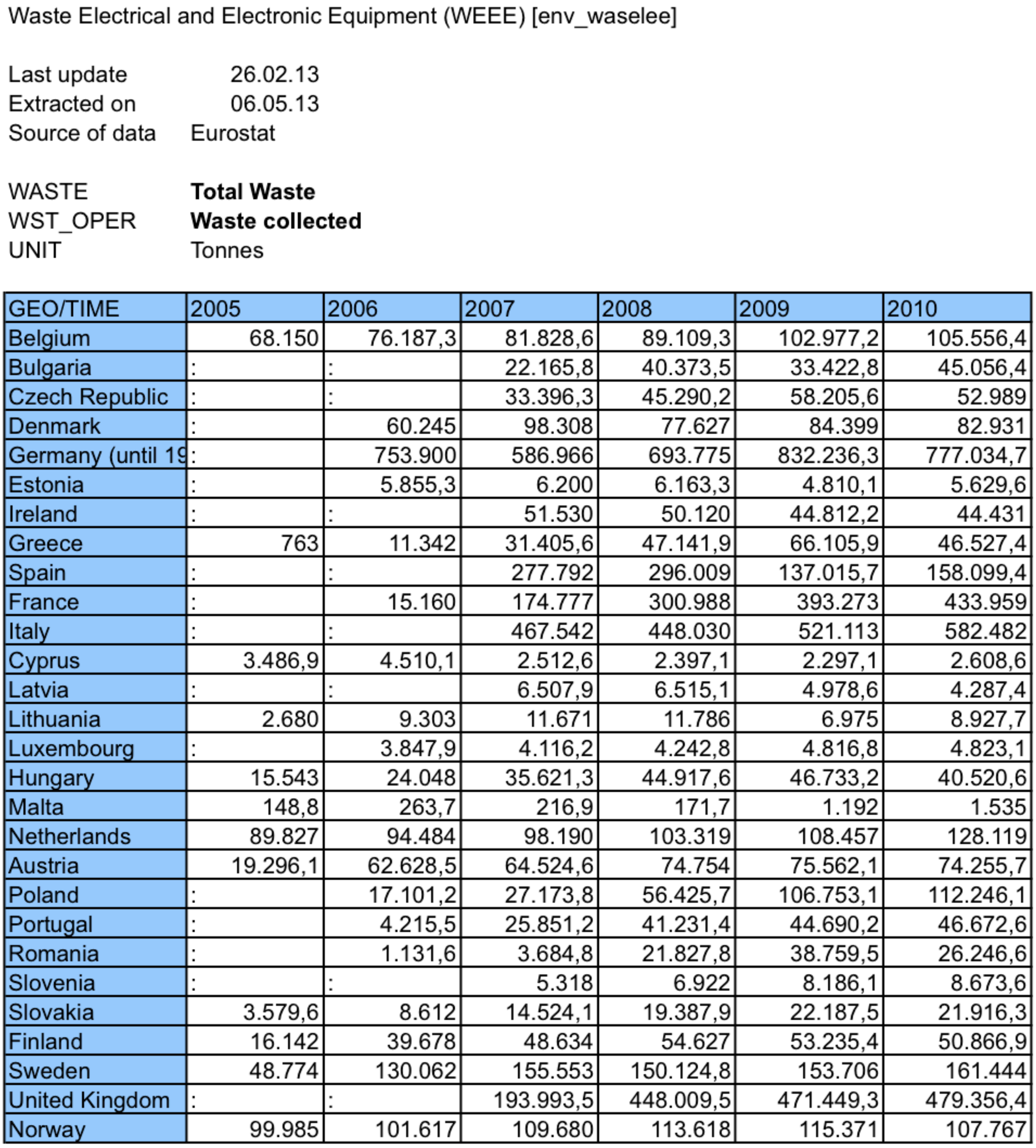
DfD is sometimes also referred as Design for "Dismantling", and thus includes considerations of EoL treatment efficiency and how to optimize separation/liberation of components and materials for recovery. This also include overall goals of reparability, refurbishment, reuse, and recycling, which constitutes to considerations around combination of different materials compositions, the assembly and mechanical connections between components and subassemblies of the product (ENSAM, 2013)(Graedel & Allenby, 2010: 119). The larger concerns in DfD are to preserve raw materials and reduce the amount of materials going to landfill. The three key aspects of this design approach include: *use & material selection*, *parts design and structure* (standardize, modular designs) and the selection and use of fasteners (ENSAM, 2013).

DfES goes further and also addresses the issues of reducing material compositions to a minimum, where it is also sought to address e.g. metals that can be thermodynamically separated so its possible to metallurgical recover them in end-processing. This for instance means to minimize the use of alloys and solders where mixing of various elements is evident, and to make both the uptake of metal elements and the use of them more sustainable and environmental friendly. This also includes the reduction of using, if any, hazardous materials (Graedel & Allenby, 2010: 129-131 + 137).

2J. WEEE Data from Eurostat

All data has been extracted from: Eurostat' webportal on the following link:

http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/



Waste Electrical and Electronic Equipment (WEEE) [env_waselee]

Last update 26.02.13
Extracted on 06.05.13
Source of data Eurostat

WASTE **Total Waste**
WST_OPER **Waste collected**
UNIT Tonnes

GEO/TIME	2005	2006	2007	2008	2009	2010
Belgium	68.150	76.187,3	81.828,6	89.109,3	102.977,2	105.556,4
Bulgaria	:	:	22.165,8	40.373,5	33.422,8	45.056,4
Czech Republic	:	:	33.396,3	45.290,2	58.205,6	52.989
Denmark	:	60.245	98.308	77.627	84.399	82.931
Germany (until 19	:	753.900	586.966	693.775	832.236,3	777.034,7
Estonia	:	5.855,3	6.200	6.163,3	4.810,1	5.629,6
Ireland	:	:	51.530	50.120	44.812,2	44.431
Greece	763	11.342	31.405,6	47.141,9	66.105,9	46.527,4
Spain	:	:	277.792	296.009	137.015,7	158.099,4
France	:	15.160	174.777	300.988	393.273	433.959
Italy	:	:	467.542	448.030	521.113	582.482
Cyprus	3.486,9	4.510,1	2.512,6	2.397,1	2.297,1	2.608,6
Latvia	:	:	6.507,9	6.515,1	4.978,6	4.287,4
Lithuania	2.680	9.303	11.671	11.786	6.975	8.927,7
Luxembourg	:	3.847,9	4.116,2	4.242,8	4.816,8	4.823,1
Hungary	15.543	24.048	35.621,3	44.917,6	46.733,2	40.520,6
Malta	148,8	263,7	216,9	171,7	1.192	1.535
Netherlands	89.827	94.484	98.190	103.319	108.457	128.119
Austria	19.296,1	62.628,5	64.524,6	74.754	75.562,1	74.255,7
Poland	:	17.101,2	27.173,8	56.425,7	106.753,1	112.246,1
Portugal	:	4.215,5	25.851,2	41.231,4	44.690,2	46.672,6
Romania	:	1.131,6	3.684,8	21.827,8	38.759,5	26.246,6
Slovenia	:	:	5.318	6.922	8.186,1	8.673,6
Slovakia	3.579,6	8.612	14.524,1	19.387,9	22.187,5	21.916,3
Finland	16.142	39.678	48.634	54.627	53.235,4	50.866,9
Sweden	48.774	130.062	155.553	150.124,8	153.706	161.444
United Kingdom	:	:	193.993,5	448.009,5	471.449,3	479.356,4
Norway	99.985	101.617	109.680	113.618	115.371	107.767

Total 2010:
3.614.962,5

Waste Electrical and Electronic Equipment (WEEE) [env_waselee]

Last update 26.02.13
Extracted on 06.05.13
Source of dat Eurostat

WASTE **Total Waste**
WST_OPER **Waste collected from households**
UNIT Tonnes

GEO/TIME	2005	2006	2007	2008	2009	2010
Belgium	68.146,6	76.143,6	81.146,3	86.939,8	98.757,4	101.772,1
Bulgaria	:	:	21.164,3	39.209	33.100,8	44.706,5
Czech Repub	:	:	32.043,8	44.613,6	56.642,9	52.118,6
Denmark	:	58.809	96.871	76.108	82.716	82.124
Germany (un	:	709.787	517.469	642.287	772.773,3	722.566,7
Estonia	:	5.800,7	6.188,8	5.894,2	4.710,8	5.573,7
Ireland	:	:	37.602	39.645	37.950,8	36.755
Greece	100	9.599	28.733,2	44.304,7	62.846,9	44.551,5
Spain	:	159.094,4	269.810	286.204	125.038,4	148.513,9
France	:	5.392	159.064	283.560	371.391	416.976
Italy	:	:	116.248	156.563	216.861	253.666
Cyprus	:	:	2.410,6	2.262,1	2.277,1	2.578,6
Latvia	:	:	6.148,1	6.086,6	4.174,4	4.170,2
Lithuania	2.680	8.999	11.295	11.321	6.828,5	8.828,2
Luxembourg	:	3.820,2	4.051	4.161,8	4.734,5	4.747,3
Hungary	15.453,7	23.817,1	35.604,4	44.850,7	46.533,4	38.645,5
Malta	42,6	35,7	6,8	16,4	581	1.394
Netherlands	88.527	92.849	95.676	100.599	102.347	121.020
Austria	18.953,5	61.378,5	61.581,6	73.207	74.785,4	72.946,6
Poland	:	5.211,7	10.280,2	36.488,6	101.390,9	106.557,7
Portugal	:	4.206,4	24.732,8	41.185,2	44.672,5	46.652,8
Romania	:	871,1	3.413	17.984,4	33.862,4	23.237,3
Slovenia	:	:	3.501	5.458	7.800,7	8.255,3
Slovakia	3.533,3	8.309,3	14.329,6	19.076,5	21.914,7	21.360,3
Finland	13.870	37.206	46.304	52.002	50.898,5	48.856,3
Sweden	43.252	115.337	137.470	139.362,8	143.136	148.895
United Kingd	:	:	184.454,1	421.270,1	457.912,2	463.157
Norway	:	36.680	70.253	62.521	74.187	77.238

Total 2010:
3.107.864,1

Waste Electrical and Electronic Equipment (WEEE) [env_waselee]

Last update 26.02.13
Extracted on 06.05.13
Source of dat Eurostat

WASTE **Total Waste**
WST_OPER **Products put on the market**
UNIT Tonnes

GEO/TIME	2005	2006	2007	2008	2009	2010
Belgium	213.821,4	249.736,1	265.728	295.085,5	287.620,5	294.530,4
Bulgaria	:	:	102.237	102.237	56.049,8	51.207
Czech Repub	:	:	202.025,5	209.055	181.844	166.063,3
Denmark	:	173.468	206.565	162.367	145.963	147.557
Germany (un	:	1.836.913	1.612.228	1.883.544	1.660.389,9	1.730.794,1
Estonia	:	18.317,9	17.930,9	35.266,2	11.204,9	13.199,2
Ireland	:	:	141.543	114.919	96.668,3	96.360
Greece	153.058	175.935	212.228	210.356	215.320	178.260
Spain	:	512.477,7	978.077	775.730	696.156	746.801,3
France	:	1.481.563	1.637.531	1.669.718	1.565.469	1.635.493
Italy	:	:	1.397.603	1.391.855	973.713	1.117.406
Cyprus	23.460,9	14.928,8	17.320,2	17.859,6	19.145	19.178,5
Latvia	:	:	36.337,8	28.360,6	15.624,6	15.289,6
Lithuania	48.502	49.798	47.940	42.602	23.585,8	23.993,6
Luxembourg	7.692,4	7.943,1	12.601,6	11.740,5	13.266	17.020
Hungary	129.299,1	135.774,5	130.381,2	135.159,7	126.814,1	124.177,8
Malta	9.854	10.094	9.443	10.001	13.728	14.291
Netherlands	:	62.125	57.218	78.215	59.610	61.696
Austria	64.318	156.809	167.194	171.667	159.993	165.810
Poland	:	865.246,2	556.471,1	594.898,8	448.331,6	487.108,3
Portugal	177.498,3	123.208	179.089,3	173.811,9	169.050	157.065
Romania	:	140.849,3	188.088,6	244.050	123.820,6	151.316,7
Slovenia	:	27.245	35.335	33.582	27.795,5	28.441,3
Slovakia	48.530,7	51.523	56.022,2	60.655,6	45.465,4	49.251,8
Finland	52.782	139.026	164.739	162.595	144.822,4	148.157,1
Sweden	84.981	226.615	285.747	234.087,9	218.707	232.403
United Kingd	:	:	803.303,5	1.350.720,8	1.546.565	1.534.575,9
Norway	390.842	187.143	208.064	208.063	172.519	181.579

Total 2010:
9.589.025,9

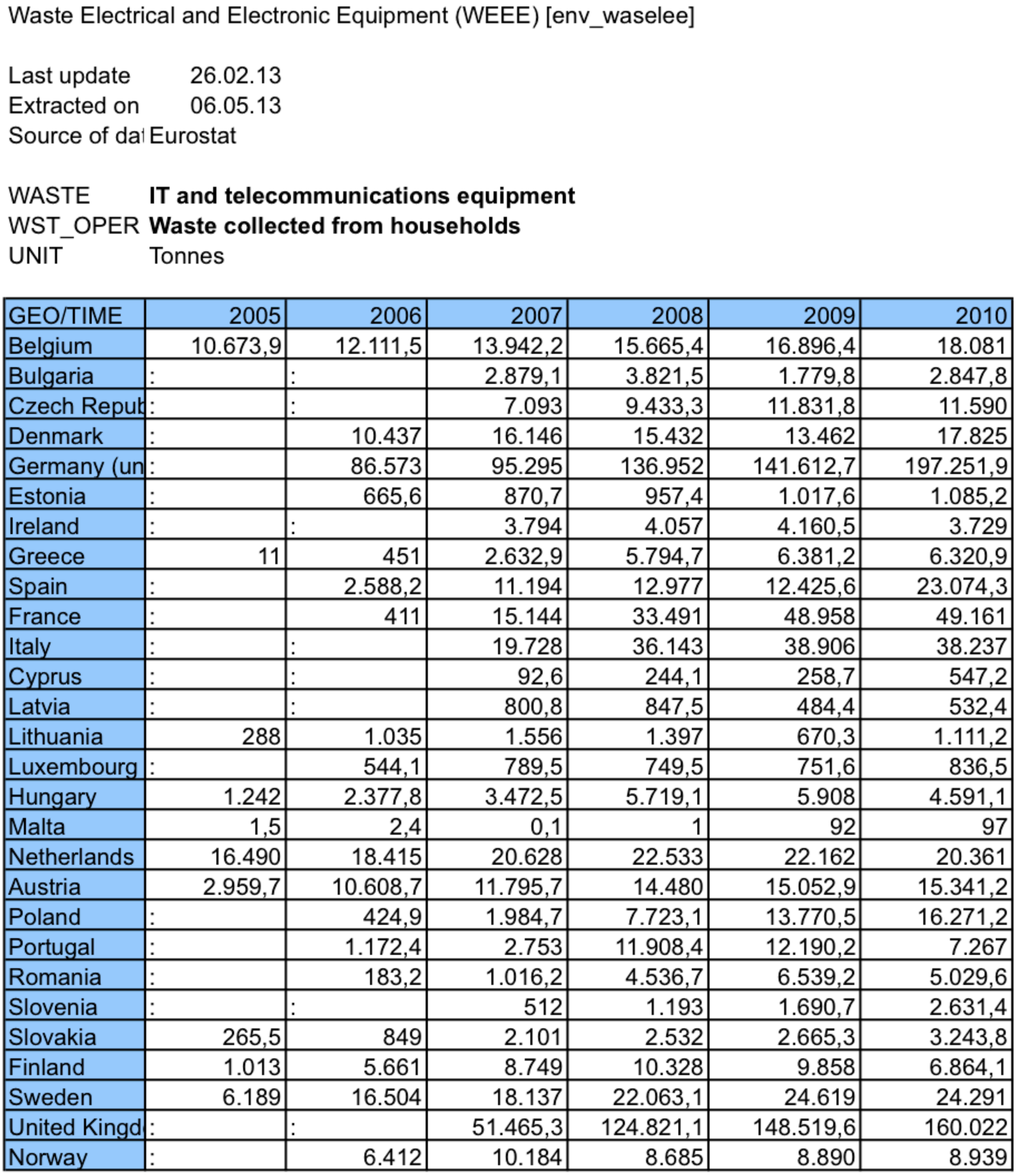
Waste Electrical and Electronic Equipment (WEEE) [env_waselee]

Last update 26.02.13
Extracted on 06.05.13
Source of data Eurostat

WASTE **IT and telecommunications equipment**
WST_OPER **Waste collected**
UNIT Tonnes

GEO/TIME	2005	2006	2007	2008	2009	2010
Belgium	10.673,9	12.155,2	14.372,9	16.284,7	17.441,6	18.625,9
Bulgaria	:	:	3.835,7	4.553,7	2.092,3	2.850,2
Czech Republic	:	:	7.270,9	9.784,1	12.348,9	11.785,3
Denmark	:	11.380	17.043	16.507	14.633	18.325
Germany (until 19	:	102.336	117.749	155.007	161.957,7	217.916,9
Estonia	:	687	870,7	970,7	1.058,5	1.131,6
Ireland	:	:	11.163	9.599	5.328,2	4.319
Greece	449	1.001	2.981,5	5.941,9	8.290,4	7.241,7
Spain	:	:	14.406	17.019	15.946,7	25.924,2
France	:	8.540	28.574	47.766	67.485	63.407
Italy	:	:	:	:	38.906	38.237
Cyprus	263,6	856,9	127,6	290,1	258,7	547,2
Latvia	:	:	800,8	853,5	491,3	561,9
Lithuania	288	1.072	1.575	1.415	686,9	1.146,9
Luxembourg	:	570,2	852,9	827,5	831	910,5
Hungary	1.242	2.377,8	3.472,5	5.719,1	6.016	5.024,7
Malta	29,4	85	49	31,4	112	104
Netherlands	16.838	18.440	21.049	23.069	22.623	20.620
Austria	3.148,2	11.365,5	13.212	15.343	15.697,2	16.331,6
Poland	:	3.067,3	8.714,7	14.948,7	15.334,2	18.082,2
Portugal	:	1.175,7	3.238,2	11.937	12.208	7.272
Romania	:	274,2	1.164,3	6.252,7	9.103,7	6.459,8
Slovenia	:	:	1.237	1.841	1.825,8	2.838,6
Slovakia	285,6	859	2.101	2.532	2.665,3	3.243,8
Finland	2.841	7.012	10.375	11.647	10.993,2	8.034
Sweden	9.440	25.174	29.782	29.590,8	30.685	31.756
United Kingdom	:	:	55.831,3	132.009,9	154.652,2	165.626,3
Norway	15.917	18.439	20.368	21.493	19.849	16.496

Total 2010:
714.819,3



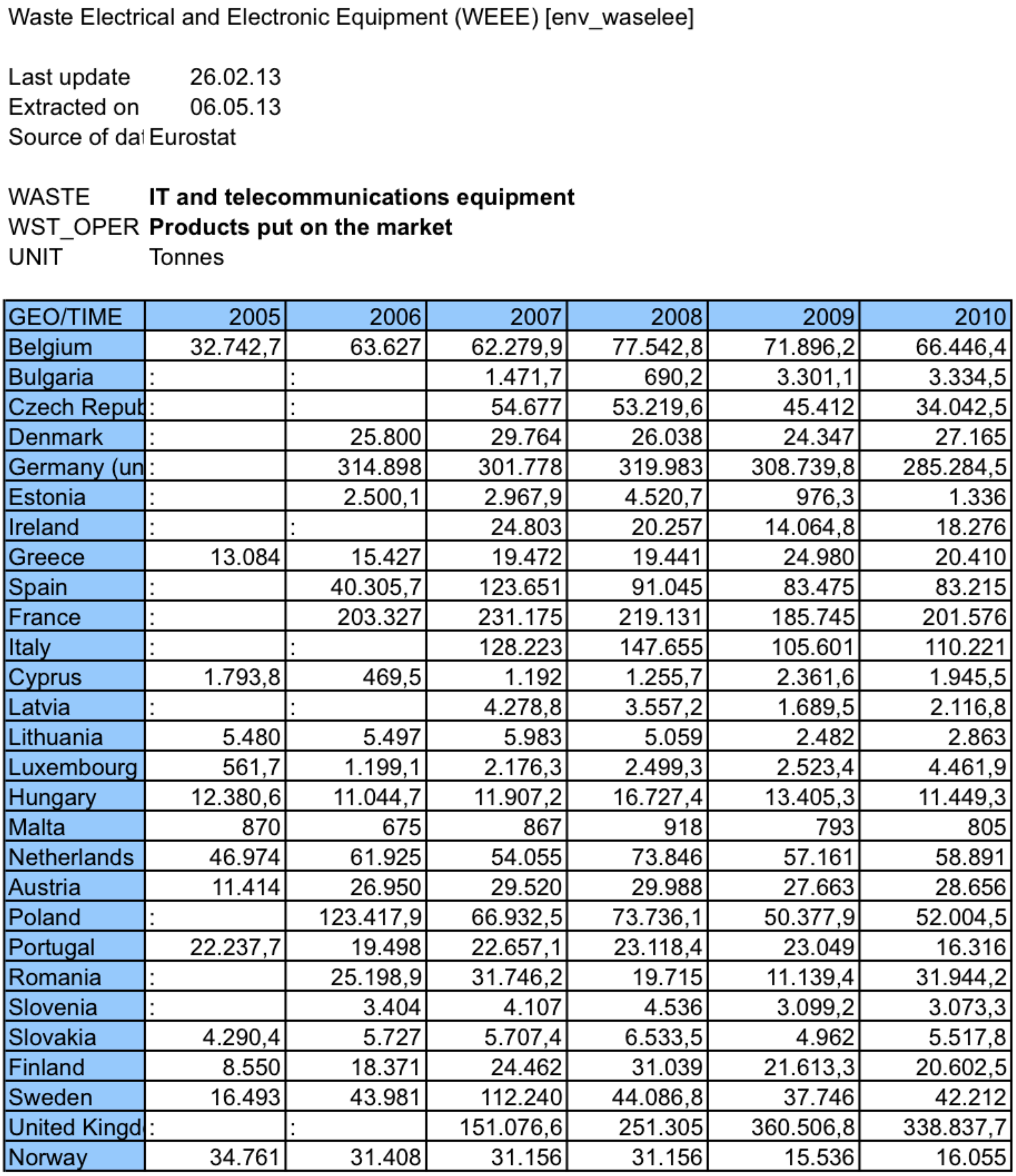
Waste Electrical and Electronic Equipment (WEEE) [env_waselee]

Last update 26.02.13
Extracted on 06.05.13
Source of dat Eurostat

WASTE **IT and telecommunications equipment**
WST_OPER **Waste collected from households**
UNIT Tonnes

GEO/TIME	2005	2006	2007	2008	2009	2010
Belgium	10.673,9	12.111,5	13.942,2	15.665,4	16.896,4	18.081
Bulgaria	:	:	2.879,1	3.821,5	1.779,8	2.847,8
Czech Repub	:	:	7.093	9.433,3	11.831,8	11.590
Denmark	:	10.437	16.146	15.432	13.462	17.825
Germany (un	:	86.573	95.295	136.952	141.612,7	197.251,9
Estonia	:	665,6	870,7	957,4	1.017,6	1.085,2
Ireland	:	:	3.794	4.057	4.160,5	3.729
Greece	11	451	2.632,9	5.794,7	6.381,2	6.320,9
Spain	:	2.588,2	11.194	12.977	12.425,6	23.074,3
France	:	411	15.144	33.491	48.958	49.161
Italy	:	:	19.728	36.143	38.906	38.237
Cyprus	:	:	92,6	244,1	258,7	547,2
Latvia	:	:	800,8	847,5	484,4	532,4
Lithuania	288	1.035	1.556	1.397	670,3	1.111,2
Luxembourg	:	544,1	789,5	749,5	751,6	836,5
Hungary	1.242	2.377,8	3.472,5	5.719,1	5.908	4.591,1
Malta	1,5	2,4	0,1	1	92	97
Netherlands	16.490	18.415	20.628	22.533	22.162	20.361
Austria	2.959,7	10.608,7	11.795,7	14.480	15.052,9	15.341,2
Poland	:	424,9	1.984,7	7.723,1	13.770,5	16.271,2
Portugal	:	1.172,4	2.753	11.908,4	12.190,2	7.267
Romania	:	183,2	1.016,2	4.536,7	6.539,2	5.029,6
Slovenia	:	:	512	1.193	1.690,7	2.631,4
Slovakia	265,5	849	2.101	2.532	2.665,3	3.243,8
Finland	1.013	5.661	8.749	10.328	9.858	6.864,1
Sweden	6.189	16.504	18.137	22.063,1	24.619	24.291
United Kingd	:	:	51.465,3	124.821,1	148.519,6	160.022
Norway	:	6.412	10.184	8.685	8.890	8.939

Total 2010:
647.179,8



Waste Electrical and Electronic Equipment (WEEE) [env_waselee]

Last update 26.02.13
Extracted on 06.05.13
Source of dat Eurostat

WASTE **IT and telecommunications equipment**
WST_OPER **Products put on the market**
UNIT Tonnes

GEO/TIME	2005	2006	2007	2008	2009	2010
Belgium	32.742,7	63.627	62.279,9	77.542,8	71.896,2	66.446,4
Bulgaria	:	:	1.471,7	690,2	3.301,1	3.334,5
Czech Repub	:	:	54.677	53.219,6	45.412	34.042,5
Denmark	:	25.800	29.764	26.038	24.347	27.165
Germany (un	:	314.898	301.778	319.983	308.739,8	285.284,5
Estonia	:	2.500,1	2.967,9	4.520,7	976,3	1.336
Ireland	:	:	24.803	20.257	14.064,8	18.276
Greece	13.084	15.427	19.472	19.441	24.980	20.410
Spain	:	40.305,7	123.651	91.045	83.475	83.215
France	:	203.327	231.175	219.131	185.745	201.576
Italy	:	:	128.223	147.655	105.601	110.221
Cyprus	1.793,8	469,5	1.192	1.255,7	2.361,6	1.945,5
Latvia	:	:	4.278,8	3.557,2	1.689,5	2.116,8
Lithuania	5.480	5.497	5.983	5.059	2.482	2.863
Luxembourg	561,7	1.199,1	2.176,3	2.499,3	2.523,4	4.461,9
Hungary	12.380,6	11.044,7	11.907,2	16.727,4	13.405,3	11.449,3
Malta	870	675	867	918	793	805
Netherlands	46.974	61.925	54.055	73.846	57.161	58.891
Austria	11.414	26.950	29.520	29.988	27.663	28.656
Poland	:	123.417,9	66.932,5	73.736,1	50.377,9	52.004,5
Portugal	22.237,7	19.498	22.657,1	23.118,4	23.049	16.316
Romania	:	25.198,9	31.746,2	19.715	11.139,4	31.944,2
Slovenia	:	3.404	4.107	4.536	3.099,2	3.073,3
Slovakia	4.290,4	5.727	5.707,4	6.533,5	4.962	5.517,8
Finland	8.550	18.371	24.462	31.039	21.613,3	20.602,5
Sweden	16.493	43.981	112.240	44.086,8	37.746	42.212
United Kingd	:	:	151.076,6	251.305	360.506,8	338.837,7
Norway	34.761	31.408	31.156	31.156	15.536	16.055

Total 2010:
1.489.058,4

Appendix III: Environmental & Social Aspects

3A. Global e-Waste

Frost & Sullivan estimated the global WEEE recycling service market to be 1086m € in 2011, with an annual growth rate of 4% into the future. This equals approx. 1175m € this year. The global recycling services market for WEEE is closely linked to the European WEEE regulation and policy targets, thus leading the development in the global WEEE recycling industry (Frost & Sullivan, 2012). Meaning that actions taken on the more mature European market will impact the world market of ICT both in pre-sale (e.g. product design, suppliers, manufacturing) and the EoL phase – directly and indirectly. The total European WEEE accumulation is expected to grow to around 12.3m tonnes in 2020 (Meskers et al., 2009: 4). This corresponds to a yearly growth rate of approx. 2,5-2,6 % per year if we calculate from the total EEE put to market in 2010 of 9.589m tonnes[86] (last statistical revision – see table 1 p. 42). The European Commission states that growth in WEEE is expected to be 3-5% per year (EC, 2012 [d]). With a conservative measure and so a growth rate of 4% per year between 2010-2020, this would be a bit higher at 14.2m tonnes[87].

At the same time mobile phones are a global phenomena, with over 1.7 billion phones shipped around the world in 2012 (IDC, January 2013[a]). As of first quarter in 2013, smartphones have overtaken the lead in the global mobile phone market from so-called feature phones, with Samsung, Apple, LG, Huawei and ZTE being the biggest vendors in that order (IDC, April 2013[b]). Thus, several hundred million phones can be expected to be shipped and sold in Europe every year, with its population of around half a billion.

3B. Gold In Mobile Phones

ICT devices and appliances possess large amounts of valuable embedded metal resources due to the concentration of precious metals when compared to other items in the e-waste stream. In this regard, mobile phones have the highest concentration in weight and volume (Hagelüken & Corti, 2010: 3). This can be exemplified by Gold (Au). Au is found in very high concentrations in printed circuit boards (PCBs) embedded in all ICT devices such as desktop, notebook and tablet computers and mobile phones (both feature phones + smartphones). Thus, an average of 30mg of Au per phone is more or less fixed in its internal circuitry[88] (Öko-institut, 2012: 38). This equals 272 parts per million (ppm) or grams per tonne (g/t) of obsolete mobile phones[89] (waste phones). Other studies set the average a bit higher to 320 g/t (Hagelüken & Corti, 2010: 3), but they probably work with higher average weights. It may not sound like much, but the average grade of native gold-

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[86] 9.590.000 x 1.025¨^10 = 12.276.010

[87] 9.590.000 x 1.04^10 = 14.195.542

[88] Based on smartphones with an average weight of 110g excluding the battery.

[89] 110g /1 kiloton = 9091 phones x 0,03 g = 272 g/t

ore in mining activities is 3,5 g/t and is predicted to decrease towards low grades of 1 g/t in the future[90] (Norgate & Hague, 2012: 53f). Due to the predicted decrease in the metal ore grade this means obsolete mobile phones possess around 100 times as much Au per t compared to virgin ore. For separated high-grade computer PCBs such as motherboards, the Au content can be expected to be even higher at 56 milligrams (mg) per item (Öko-institut, 2012: 21). Thus, recycling and recovery of resources, especially obsolete ICT, from the e-waste stream possess literally a golden opportunity for closing the cycle – and so for many other elements too.

These phones will someday become obsolete, and as it is now in Europe, largely not collected or treated for their valuable metal resources (cf. section 5.2). To draw a visual example of the value, we can look Au again as one of the possible lost resources embedded in phones. The amount of Au that is used in production of 1.7bn phones equals a little over 2bn €. The OEM that shipped most mobile phones in 2012 was Samsung with 111m units (IDC, 2013[a]), and so those phones have an embedded value of 135m € in Au alone[91] - approx. 1.2m € in Au per million phones. Thus, recycling and recovery of resources in ICT, for example mobile phones, shows great economic value.

3C. Environmental Impacts From Gold

When looking at the environmental and social costs of mining and metal production activities, possibilities of increasing recycling and recovery of metals become very important. Immense GHGe, creation of solid wastes and wastewater is embodied in the primary production of Au as well as toxic cyanide leaching in the extraction process (Norgate & Hague, 2012: 58). Additionally, Au is also regarded as a conflict metal in non-commercial mining activities (Young & Dias, 2011: 2f).

Hageluken & Meskers report that 300 t/yr[92] of primary Au production is going to electrical and electronic equipment (EEE). For comparison, Copper (Cu), quantitatively one of the most used metal resources for electronics, accounts for 4.5m t/yr, (Hagelüken & Meskers, 2010: 166). By using these numbers and multiplying with the average CO_2e from primary production of Au and Cu found in the table underneath, we can estimate the carbon footprint from these metals utility in EEE today.
Selection of CO_2e From Primary Production of Some Metals

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[90] Native gold has high purity content, around 90% gold ore, but the grade of gold deposits (how much mass per tonne) is dropping and can be expected to level off around 1 g/t in 2050.

[91] 111bn Samsung phones X average 30mg of Au/phone = 3.33bn mg. Converted to troy ounce = 107062 X gold price at 1643 USD (2012 average price) (BASF, 2013) = 176m USD (135m EUR). Same calculation method, with 1.7bn phones = 2.7 USD (2,07bn EUR).

[92] A newer study indicate that this number has now grown to 320t Au together with 4500t of Ag, accounting for a market value of approx. 21bn USD (UNU, July 2012)

Metal	Carbon Footprint kg CO_2-Equiv./kg	Metal	Carbon Footprint kg CO_2-Equiv./kg
Cadmium	0,80	Antimony	12,9
Iron	1,7	Tin	17,2
Lead	2,1	Lithium	21,1
Manganese	2,6	Chromium	26,8
Copper	3,2	Rare Earths (Neodymium)	38,6
Zinc	3,4	Magnesium	73,8
Titanium	4,6	Silver	101
Tellurium	7,5	Indium	154
Molybdenum	7,7	Gallium	205
Cobalt	8,3	Tantalum	260
Nickel	10,9	Platinum metals[a]	14.823
Aluminium	12,4	Gold	18.727

Above illustration adopted from (Schmidt, 2012: 2).

- 300.000 kg Au X 18.727 kg CO_2e/ 1000 = 5.618.100 t (5,6m t CO_2e)
- 4.500.000.000 kg Cu X 3,2 kg CO_2e/ 1000 = 14.400.000 t (14,4m t CO_2e)

This means that even though primary Cu production for EEE is seemingly 15.000 times bigger than Au, the CO_2e from Au production going to EEE correspond to over 1/3 of that of Cu production.

3D. General Environmental and Social Impacts from Mine to Product

It is difficult to uncover all of the environmental and social aspects of mining minerals, refining metals and finally producing electronics. However, there are some overall impacts, which has been extensively reported and examined, especially since the early 2000s. GeSI and EICC[93] are examples of industry coalitions, NGOs and intergovernmental organisations working towards establishing sustainability in supply chains. On the social side one of the main focuses since 1996 has been on the problems regarding so-called ‘conflict metals’ (Young & Dias, 2011). This is mining that go about commercial activities, conflicting human rights and providing financial inputs for violent conflicts and war. Here, Transparency of supply chains has been sought uncovered through either tracking or tracing[94] the metals. Target metals, originating from conflict zones such as Zambia and the DRC, especially include: gold, tin, tantalum, tungsten and cobalt (Resolve, 2010: 5) (Young & Dias, 2011: 2). Here, the 2010 documentary “blood in the mobile” reviled a deep visually insight into the mining of Tin in the DRC and the social consequences it has on the population (Poulsen, 2010). Friends of the Earth did a half-year on site study into Tin production in Indonesia, uncovering both the environmental and additional

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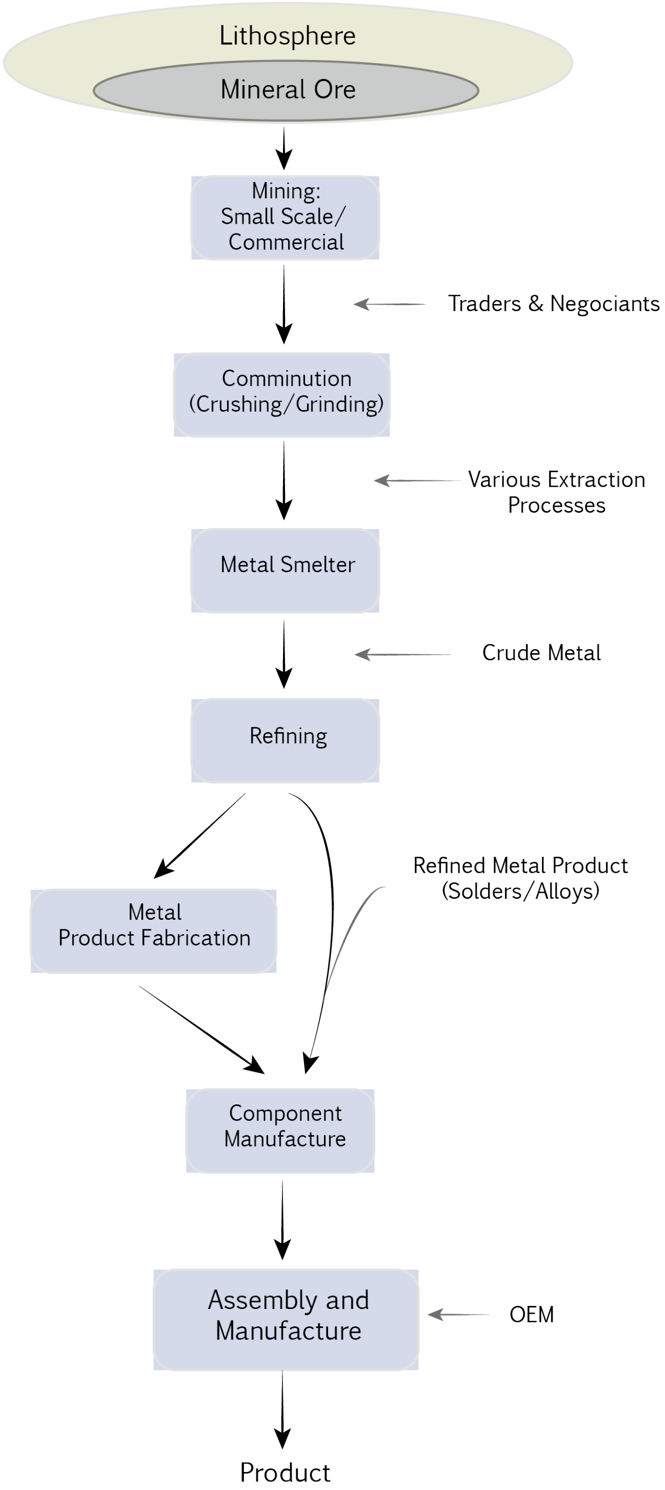
[93] Global e-Sustainability Initiative (GeSI) and Electronic Industry Citizenship Coalition (EICC) (Resolve, 2010:

[94] Tracking from mine to product, tracing from product to mine.

social aspects of mining activities. This included various problems, such as: Pollution of drinking water, general dangerous working conditions, injuries and fatal accidents when pits collapse, loss of soil fertility, landscape change, silt and sludge run-offs to sea killing marine life, damaging coral reefs and impacting local communities fishing livelihood (Friends of the Earth, 2012: 13).

Rare Earth Elements (REEs) can also be used as an example of serious environmental impacts. The production of REEs consumes huge quantities of water, acidic substances and energy for the extraction, separation and refining. Additionally REE elements are geologically associated with radioactive elements such as Thorium and Uranium. This implies huge mitigation costs in terms of environmental security and workers safety. The release of hazardous chemicals and radioactive elements into the environment and groundwater is thus significant results of REE production (Massari & Ruberti, 2012: 42). A general metal supply chain has been assembled see next page:



‘Lifecycle from Ore to Pre-commercialisation’. Based on traced/tracked supply chain descriptions of Tin, Tantalum, Cobalt (Resolve, 2010) LSA on Gold (Young, 2011) LSA of Copper (Van Beers, 2003) and Tin (Izard & Müller, 2010). The supply chain steps may vary in reality but main steps included in the figure are present in all of the metal cycles and thus represent a general picture.

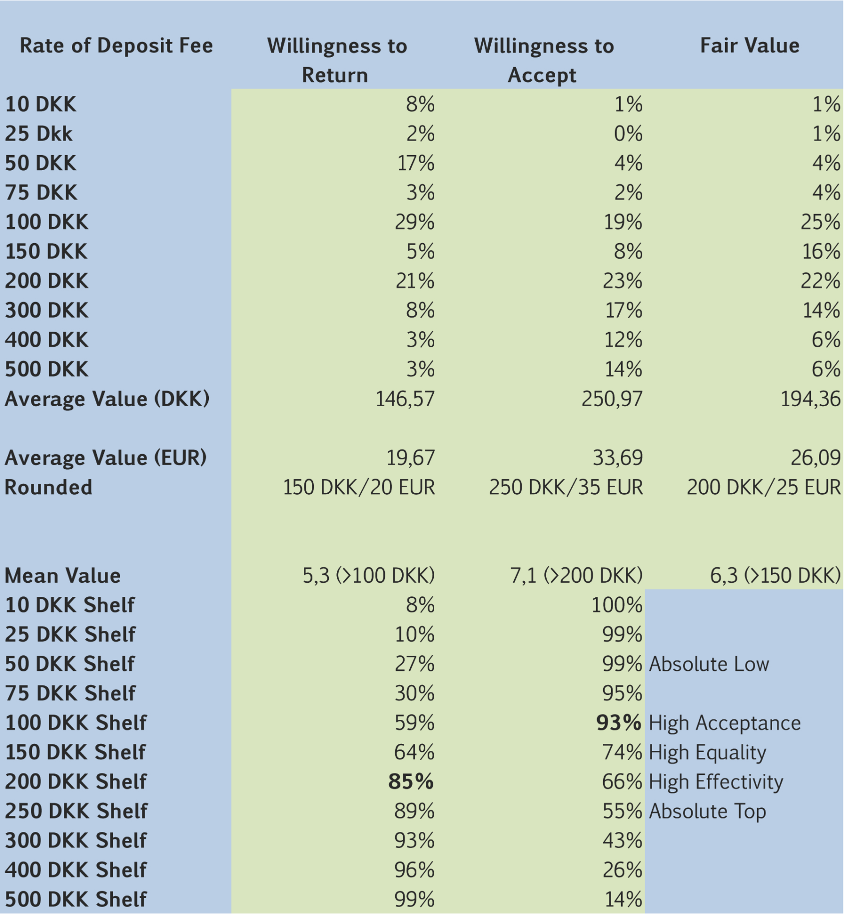
Appendix IV – Estimates & Aspects for a DRS

4A. Repayment Schemes

The market has been transformed in recent years, where smartphones are pressuring out feature phones, which are losing market shares rapidly (DST, 2013: NR225). The largely more expensive smartphones have gained extra ground due to affordable repayment schemes, which were introduced around 2011 by the four MNOs in Denmark (TDC, Telia, Telenor and HiG3). Consumers can now choose to pay down the original retail price over an optional 6, 12, 18 or 24 months, by subscribing to a MNO at the same time. The repayment model has allowed MNO retailers to gain the full retail price and capture costumers for their normal operator services. Especially with the largely more expensive smartphone market, they are now competing on tele-service products instead of loosing profits by competing by providing cheap mobile phone offers (Berlingske Business, 2011: a+b)(. This business model is also common outside of Denmark. However, the actual subscription is thus separate from any repayment scheme and cannot be more than maximum 6 months (forbrug.dk, 2013). This means that consumers can leave the operator, for another, after 6 months, but still have to pay off the phone for the rest of the contract period or by down paying the leftover value. Nevertheless, it can be assumed that most consumers stay with the particular operator for the whole time being. These repayment schemes have on the other hand also lead consumers to access the more expensive smartphone market (MobilabonnementsLuppen.dk, 2013).

4B. Estimate of Deposit Size

Responses to Q12-14 in the consumer survey (se appendix V: 5A) were used to make the following estimate of the deposit size for a DRS on mobile phones:



Rate of Deposit Fee	Willingness to Return	Willingness to Accept	Fair Value
10 DKK	8%	1%	1%
25 Dkk	2%	0%	1%
50 DKK	17%	4%	4%
75 DKK	3%	2%	4%
100 DKK	29%	19%	25%
150 DKK	5%	8%	16%
200 DKK	21%	23%	22%
300 DKK	8%	17%	14%
400 DKK	3%	12%	6%
500 DKK	3%	14%	6%
Average Value (DKK)	146,57	250,97	194,36
Average Value (EUR)	19,67	33,69	26,09
Rounded	150 DKK/20 EUR	250 DKK/35 EUR	200 DKK/25 EUR
Mean Value	5,3 (>100 DKK)	7,1 (>200 DKK)	6,3 (>150 DKK)
10 DKK Shelf	8%	100%	
25 DKK Shelf	10%	99%	
50 DKK Shelf	27%	99%	Absolute Low
75 DKK Shelf	30%	95%	
100 DKK Shelf	59%	**93%**	High Acceptance
150 DKK Shelf	64%	74%	High Equality
200 DKK Shelf	**85%**	66%	High Effectivity
250 DKK Shelf	89%	55%	Absolute Top
300 DKK Shelf	93%	43%	
400 DKK Shelf	96%	26%	
500 DKK Shelf	99%	14%	

4C. Potential Value Generation from Collection of Historical Phones

Number of Potential Collected Historical Phones	2m (20%) *[Million DKK/EUR]*	4m (40%) *[Million DKK/EUR]*	6m (60%) *[Million DKK/EUR]*	8m (80%) *[Million DKK/EUR]*
Overall Socio-Economic Value (24,61 DKK/phone)	49,22/6,6	98,44/13,2	147,66/19,8	196,88/26,42
Total Metal Resource Revenue (15,97 DKK/phone)	31,94/4,28	63,88/8,57	95,82/12,8	127,76/17,14
Possible 'Small Refund' Load (10,00 DKK/phone)	20/2,68	40/5,36	60/8	80/10,73
Revenue After Refund (5,97 DKK/	11,94/1,6	23,88/3,2	35,82/4,8	47,76/6,4
Collected Weight Measure (109 g. /per phone)	218.000 t	436.000 t	654.000 t	872.000 t

'Estimate of Value Generation from Collection Historical Phones'. All values are based on the analysed socio-economic estimates described in section 6.2.1. These values are multiplied by the potential number of collected historical phones as expressed in the table above.

4D. Costs of Setting Up a DRS for Mobile Phones

Calculation of the expected cost of setting up a DRS for mobile phones is based on data inputs from selection of sources. Some estimates and calculations were conducted for the Danish EPA by the consultancy Grontmij, around the costs and benefits of setting up retail based collection for small-WEEE and light sources in Denmark in correlation with the new order in the European WEEE directive. The author have been given exclusive right to these documents why it is necessary to mention that they are not official at this time of writing. Therefore, if necessary, access has to be granted by the Danish EPA.

Estimating the Total Available Public/Private Collection Points for a DRS

Public: collection points for e-waste (WEEE) is by default arranged and provided by the 98 municipalities in Denmark. Data is taken from official the DPA-system web portal DPA-system, 2013: b). By summing the total number from each municipality there was found 600 available sites. Even though this number is based on official data a slight uncertainty can be expected, since it is unclear if all of the collection points would be suitable for establishing a secure and closed site. However, most site are expected to be able to provide general collection of WEEE thus needs security to prevent scavenging - why the full sum is used in this study.

Private: Possible available collection points is summed from collecting official data on retail stores in Denmark, from a wide selection of chain stores selling mobile phones, listed here:

- ***Hi3G*** [37] (MNO retailer) www.3.dk,
- ***Telenor*** [86] (MNO retailer) excl. wholesale and stores in Expert (consumer electronics) incl. stores in **Bilka** and **Føtex** (supermarkets) www.telenor.dk.
- ***Telia*** [61] (MNO retailer) incl. partner stores www.telia.dk.
- **TDC** [52] (MNO retailer) excl. wholesale www.tdc.dk.
- ***Computercity*** [10] (consumer electronics) www.computercity.dk.
- ***Elgiganten*** [29] (consumer electronics) www.elgiganten.dk.
- ***Eplehuset*** [7] (consumer electronics) www.eplehuset.dk.
- ***Expert*** [79] (consumer electronics) www.expert.dk.
- ***Fona*** [61] (consumer electronics) www.fona.dk.
- ***Humac*** [11] (consumer electronics) www.humac.dk.

Additionally 20% is added to the total 433 stores, since this number only represent chain stores, thereby not independent retailers, adding up to 520 in total. This was also done in the study from Grontmij (2013: 2).

Estimating the Collection Rate and Load Per Site

The latest statistic, report 1.91m mobile phones where sold in Denmark in 2011 and 2m were estimated for 2012, which we can use as a fair overall measure (BFE, 2012: 27f). In Denmark, opening days cannot be ensured for a whole week and around 17 official holidays + Sundays should be accounted over the year, which is why 300 possible collection days would be a fair estimate. This corresponds to 25 days a month. With these estimates we can calculate the average number of phones returned per collection point, as shown in table. 50% is set as the lowest acceptable limit after full-scale introduction of a DRS, while 100% is regarded as difficult to achieve. However, some of the historical phones will also be handed in the medium term, which will result additional collection in the first couple of years.

National Collection Rate (of 2m mobile phones)	50%	60%	70%	80%	90%
Number of phones per day	2,97	3,57	4,16	4,76	5,35
Number of phones per month	74,4	89,3	104,2	119	134
Number of phones per year	893	1071	1250	1428	1607
Weight of phones per month (kg)	8,1	9,7	11,3	12,9	14,6
Weight of phones per year (kg)	97,3	116,7	136,3	155,6	175

'Average Estimated Collection Rates per Collection Point'. 50% collection corresponds to 1m collected phones, while 90% corresponds to 1,8m. The collected number is divided by a total of 1120 sites and so further by one day, one month (25 days) and a year (300 days). The weight-based estimates are calculated from the basis of 109 g. per phone estimated in The Danish EPA (2013: 89).

Estimate of Storage Capabilities and Transport

The average mobile phone retailer must be considered to have roughly small storage capacities, why some stores might be in the range of 20-40 m2, while others will be larger than the 400 m2, which is targeted for collection in the new WEEE-directive (cf. section 5.2). Public recycling stations are not considered to have general storage problems.

Considering the mix of very different available sites and especially small retail stores, we can assume that around 50% of these smaller sites, would need to have pick-ups on a more regular basis. Here a storage capacity of maximum 50 kg of collected phones could be set as a reasonable limit. With a national collection rate of 50% this would amount to 2 pick-ups/yr. and with a high collection rate at 90% to approx. 3.5 pick-ups/yr. Large retail stores would only need to have 1 yearly pick up, so the collected phones could be registered in the yearly account. Public recycling stations already function as main collection site for the CROs, why these wouldn't need additionally pick-ups. However, transport in between smaller and larger public recycling stations might be needed.

In the socio-economic analysis from Niras they estimated the cost of transporting 1 kg collected phones to 0,02 DKK, for an average 50 km. distance in Denmark[95]. This was based on prices from a major Danish transport company, which the calculation accounted for a 1000 kg load of e-waste (The Danish EPA, 2013: 92f). In this situation, small pick-ups at 50 kg boxes are thus expected at 50% of the retailer based collection points (260 sites). Therefore, the cost is set at 30 times higher, since the load is 20 times smaller and additionally km. plus the use of smaller trucks must be accounted for between each site. That gives us total cost 0,60 DKK/kg/phones

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[95] Based on average transport cost from collection site to pre-processing plant.

from *small retail collection points*. For the *larger retailer collection points*, the cost will be accounted as 0,60/3,5, which equals to a reduced cost of 0,17 DKK/kg/phones, making up for only 1 pick-up per year. With additional transport between *public recycling stations* and the CROs main collection sites, the cost of 0,02 DKK/kg/phones is used. However, transport cost is a very low in the final picture.

Administration, Logistics and Materials

In a new analysis from the consultant bureau Grontmij to the Danish EPA, the costs of setting up a retailer based collection system for *very small WEEE* is calculated and estimated. Since their scope was slightly different, some of the values were slightly modified. However, at all collection points workers need to be educated in the new DRS system, people who are unfamiliar with the deposit-refund system require help & information, plus formal daily tasks of emptying collected phones in a final safety box. This includes 1,5 hr. for basic training and 0,5 hr. a week pr. store, corresponding to 2200 DKK in the start up phase and 5200 DKK per collection point/yr (Grontmij, 2013: 5). Using the same estimates as Grontmij, administration and supervision by the public authorities (e.g. carried out by the Danish EPA), are accounted as 1,4m DKK for start up and 1m DKK for running costs. Implementation costs for new materials at each site can be accounted as 4070 DKK, while running company costs for extra administration and logistics per site at 3150 DKK (Grontmij, 2013: 4)[96].

This gives us a perspective or estimate on the initial costs of implementing DRS for mobile phones, as viewed in the table:

Initial Costs of DRS for Mobile Phones	Public Site (600)	Small Retail Store (260)	Large Retail Store (260)	Start-Up Phase (first step)	Running Cost/yr. (second step)
Transport (175 kg/yr x nr. of sites)	2.100	27.300	7.735		37.135
Start-up Costs (2200 DKK x nr. of sites)	1.320.000	572.000	572.000	2.464.000	
Runnings Costs (5200 DKK x nr. of sites)	3.120.000	1.352.000	1.352.000		5.824.000
Public Administration (Fixed)				1.400.000	1.000.000
Administration & logistics (3150 DKK x nr. of sites)	1.890.000	819.000	819.000		3.528.000
Materials Costs (4070 DKK x nr. of sites)	2.442.000	1.058.200	1.058.200	4.558.400	911.680
Total:				8.422.400	11.300.815
Total (Rounded)				8,42m DKK/1,13m EUR	11,3m DKK/1,51m EUR
Total (First Year)					19,7m DKK/2,65m EUR

'Initial Costs of Implementing a DRS for Mobile Phones'. Calculations based on a 90% collection rate to express costs approaching full system capacity. Cost definitions above are multiplied with the number of sites, except for transport, which is calculated from the estimated collection of 175kg/yr X differentiated pick-up costs X the number of sites.

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[96] Grontmij accounted for 2163 physical sites (online retailers subtracted), which is used to divide their total number of each cost value, ending up with a cost *per site* apart from a total. The public administration and supervision costs are accounted as equal to their total estimates, since most of the tasks in this cost category are expected to be carried out, no matter the size of the system. This also keeps calculations conservative. Grontmij accounted 2,4 M in porto to online retailers, which is subtracted from the running company costs. They also accounted 80.000 DKK in waste sales, which has been ignored here since this value is a bit unreliable.

Uncertainty in the Final Estimate

The calculation is made to express an overall estimate on how much a DRS system would cost to implement. Therefore, it should not be seen as a full CBA of a DRS implementation. The estimate is vitiated with some uncertainty, since all values are taken from secondary sources and a set of values had to be qualitatively estimated. However, it has been sought to be as detailed as possible, use conservative values and take what is found the most important costs into account, hence to give a good foundation for the further assessment. The high collection rate of 90% was obviously chosen to express the highest costs of the system. With a lower collection rate of e.g. 50%, the values of transport and administration & logistics could be adjusted a bit down. However, this would not change the picture significantly, since all other values can be seen as fixed system costs. This would therefore mean that more deposits would be unclaimed and fewer funds from sale of resources would go in to the system.

Appendix V – Empirical Studies

5A. Consumer Survey on New Sale- and Collection Models for Mobile Phones

The survey was originally conducted in Danish and so has been translated to fit in this study. The survey was designed; so respondents only had information about the sender, the expected time consumption (5-7 min.) and theme "*consumer survey on new sale- and collection-models for mobile phones"*. The survey was done using several page-turns; so depending on how one responded questions would come random and visually hidden from one to the next, urging people to focus solely at the questions in hand.
The survey was also tested five times by different individuals, to assess and qualify the questions around formulations, options, forms, order and time consumption.

The survey contains 24 questions in total. Here 17 is the primary questions related to preferences on: *ownership, purchase, use, repair, service, warranty, reuse, lease, deposit-refund and disposal of mobile phones*. Additionally 3 optional questions around environmental, social and health information in purchase situations, was consciously added to the end – to avoid people being affected by their political *good will* from the start. However, these 3 questions obtained almost full responses as well. All questions were done using multiple- or single-choice forms and ratings, which gives a fast and easy response time and is simpler to quantify in the post processing of the data. This can in some cases generate so-called "fast-clicks" by the respondent. To address this problem, a limited amount of questions was made on the basis of a short paragraph text, were the respondent was encouraged to reflect carefully about the specific questions asked in the form.

However, most questions were carried out as being practical and preference oriented, in the likes of: "How did you purchase your last mobile telephone", or, "How do you rate this from 1-5" or "which of these option would you prefer".

A short setup paragraph description was given to the first questions around leasing and deposit- and refund-systems (Q11), so the respondent had an idea of how it might play out in reality – placing a deposit and getting the refund on return. No political leads or facts were given here, such as problems around the e-waste generation e.g. its environmental externalities or social costs.

Since 98% of the Danish population posses' a mobile phone (DST, 2013: a), it is believed that there is a fairly good chance for replicating this study and that the data is valid and reliable to an overall degree. Reasons for this is as followed: All questions were aimed at the *experience* people have had or how they *preferred* one situation from another, in relation to mobile phones. It is thus assumed that since practically every Dane have experiences with owning a mobile phone, this survey could have been carried out practical anywhere in the country or the questions could have been taken to a national level. However, the actual results must, as also stated in section 2.5.2, be backed by additional research to be viewed representative for Denmark as a whole.

No questions where repeated in a modified sense, to avoid twisted results. In addition, there is a very high certainty that responses to a question like *"how many used phones do you posses at home"* has given a close or nearly a true picture of the reality since there is a little reason for twisting this kind of answer. However, as also explained in in section 2.5.2 it has been sought to conservatively use the results as merited indicators of consumer preferences around mobile phones.

The political position wasn't listed among the personal details questions, because it was believed a true picture on the national demography couldn't be obtained, with the targeted number of respondents and the low age difference. Instead educational background was checked, since people from higher educations here are expected to have a larger overview on social questions in general.

The last 3 optional questions (Q22-24) were also the most political of the total 20, why these responses must believe to have a slightly lower validity than the rest of the answers. To combat this problem, I carefully made sure not to post the survey to groups of people I new had a general interest in environmental and social issues – for instance not sending it to people from the institute.

The survey results is as followed:

Q1: Age	Number of Respondents (All)	Percentage (%)
18-19 yr	19	7
20-29 yr	207	71
30-39 yr	42	14
40-49 yr	12	12
50-59 yr	10	3
60 plus yr	1	0

Q1: Gender	Number of Respondents (All)	Percentage (%)
Men	121	42
Women	169	58

Q3: Education Level (last finished)	Number of Respondents (All)	Percentage (%)
Primary School	17	**6**
High School	83	29
Vocational Training	15	5
Higher Education (Short)	12	4
Higher Education (Medium)	20	7
Bachelor (Academia)	82	28
Higher Education (Long/Master)	61	21

Q4: Type of Primary Mobile Phone	Percentage (%)
Feature-Phone	20%
Smart-Phone	80%

Q5: Personal Preferences When Purchasing a New Mobile Phone	Average Score (on a 5 level scale)	1	2	3	4	5	Total Points	Level With Most Entries
Price (on unit)	3,9	9	54	192	340	525	1120	5
Brand	3,1	30	124	240	296	220	910	3
Design, Aesthetics, Look, Weight etc.	3,8	8	64	189	368	475	1104	5
Technological Features	3,8	10	50	186	420	440	1106	4
Quality, Durability, Materials	4,0	3	24	186	448	505	1166	4
Shock, Dust and Waterproof	2,9	30	172	264	228	145	839	3
Software, OS, Apps	3,5	23	92	201	332	355	1003	4
Energy Use (Battery Life)	3,4	12	80	273	400	235	1000	4
Environmental and Social Profile	2,7	57	164	240	180	130	771	2
Easy Repair-Ability	2,5	66	190	213	168	80	717	2

Q6: Personal Preference on Purchase Method	Number of Respondents (All)	Percentage (%)
Purchase at Full Sale Price	114	39
Purchase at Reduced Sale Price Through Repayment Scheme + Subsciption to Tele-Operator	104	36
Purchase Used (e.g. From Friend, Online - With No or Limited Waranty Left)	72	25

Q7: Last Purchase Method of Present Mobile Phone	Number of Respondents (All)	Percentage (%)
Purchased at Full Sale Price	74	26
Purchased at Reduced Sale Price Through Repayment Scheme + Subsciption to Tele-Operator	121	42
Purchased Used	37	13
Didn't Purchase, But Acquired a Used and Free Mobile Phone (From Friend, Family or by Acquaintance)	58	20

Q8: Preferences When Selecting Tele-Operator (Max 3 entries per respondent)	Number of Entries (724)	Percentage (%)
Price/Monthly Payment (Basic Services - e.g minutes of talk, mms/sms, data and fees)	285	39
Network Coverage (on GSM, 3G and 4G LTE)	171	24
Extra Services (Music Services, Online TV, Discounts on e.g. Theatre, Movie, Retail Stores and Festivals Tickets, Free Talk Services etc.	54	7
Service- and Repairs (Helpfull staff and Hotline, Quick Repair time, Quick Services on Software/Hardware Failures)	60	8
Optional Extended Waranty Services (exceeding the warrenty and including e.g. coverage of physical failures/damages on screen, battery, from water etc.)	22	3
Period of Submission/No Submission	132	18

Q9: Opinion About The Possibility of a Deposit & Refund System For Mobile Phones	Number of Informant (All)	Percentage (%)
Good Idea	249	86
Bad Idea	14	5
I Don't Know	27	9

Q10: Number of Used or Obsolete Mobile Phones at Home	Amount	Number of Respondents (All)	Total Phones per Category
Zero	0	39	0
One	1	84	84
Two	2	87	174
Three	3	51	153
Four	4	17	68
Five	5	12	60
Total	539		
Average	1,86		

Q11: Reasons for Storing Used or Obsolete Mobile Phones at Home	Number of Entries (427)	Percentage (%)
Use it/them as a backup for the one I have now	177	41
Use it/them for travels, festivals or on holidays	103	24
I haven't rememberet to dispose it/them at the recycling station	38	9
It has been too difficult to dispose it/them from where I live	26	6
I forgot it/they existed	73	17
I dont know	10	2

Q12: Lowest Value (Willingness to Return)	Number of Respondents (All)	Percentage	Total Value	Interval (1-10) x Entries
10 DKK	23	8%	230	23
25 Dkk	5	2%	125	10
50 DKK	48	17%	2400	144
75 DKK	10	3%	750	40
100 DKK	85	29%	8500	425
150 DKK	14	5%	2100	84
200 DKK	61	21%	12200	427
300 DKK	24	8%	7200	192
400 DKK	10	3%	4000	90
500 DKK	10	3%	5000	100
	DKK	**EUR**	**Rounded**	**Mean Value**
Average Value	146,5689655	19,67368665	150 DKK/20 EUR	5,3

Q13: Highest Value (Willingness to Accept)	Number of Respondents (All)	Percentage	Total Value	Interval (1-10) x Entries
10 DKK	3	1%	30	3
25 Dkk	0	0%	0	0
50 DKK	12	4%	600	36
75 DKK	6	2%	450	24
100 DKK	54	19%	5400	270
150 DKK	22	8%	3300	132
200 DKK	67	23%	13400	469
300 DKK	49	17%	14700	392
400 DKK	36	12%	14400	324
500 DKK	41	14%	20500	410
	DKK	**EUR**	**Rounded**	**Mean Value**
Average Value	250,9655172	33,68664661	250 DKK/30-35 EUR	7,1

Q14: Fair Value (Political Consumer)	Number of Respondents (All)	Percentage	Total Value	Interval (1-10) x Entries
10 DKK	4	1%	40	4
25 Dkk	4	1%	100	8
50 DKK	13	4%	650	39
75 DKK	11	4%	825	44
100 DKK	72	25%	7200	360
150 DKK	45	16%	6750	270
200 DKK	65	22%	13000	455
300 DKK	42	14%	12600	336
400 DKK	18	6%	7200	162
500 DKK	16	6%	8000	160
	DKK	**EUR**	**Rounded**	**Mean Value**
Average Value (Intervals)	194,362069	26,08886832	200 DKK/25 EUR	6,3

Q15: Previous Experiences With Technical/Mechanical Damage on Mobile Phone	Number of Respondents (All)	Percentage (%)
Yes, and I Submitted the Handset for Service & Repair	115	40%
Yes	88	30%
No	87	30%

Q16: Experience With Time of Repair	Number of Respondents (114)	Percentage (%)	Repair Done Within
1 day	12	11%	
1-3 days	11	10%	
4-7 days	32	28%	1 Week >49%
8-10 days	18	16%	
11-14 days	19	17%	1-2 Weeks >35%
15-21 days	5	4%	
21+ days	4	4%	2-3 Weeks >8%
Independent Repair Shop (day-to-day)	13	11%	Same day

Q17: General Satisfaction With Service & Repair From Last Experience.	Number of Respondents (102)	Percentage (%)	Total Value
Very Unsatisfied	9	9%	9
Semi Unsatisfied	18	18%	36
Neutral	20	20%	60
Semi Satisfied	24	24%	96
Very Satisfied	25	25%	125
I Don't Know	6	6%	6
Average Value of Satisfaction	3,3		

Q18: Dissatisfactory Experiences From last Submission of Mobile Phone for Service & Repair at the Retailer	Number of Respondents (110)	Percentage (%)
Too Long Service & Repair Time	31	28%
Bad or No Loaner Phone During the Time of Service	32	29%
Unuseful or Bad Staff Service	17	15%
Unsatisfied With Service & Repair/ Didn't Solve the Actual Problem	18	16%
Confussion/Missing Transperens About Warranty and Covered Expenses	12	11%

Q19: Experiences With Technical/Hardware Damage to Mobile Phone	Number of Entries (390)	Percentage (%)
Broken/Technical Flaw On Screen	94	24%
Damaged Battery	82	21%
Broken Microphone/Speaker	45	12%
Broken Camera	9	2%
Damaged Port or Plug	28	7%
Broken Keys/Casing	55	14%
Unable to read SIM or Memory Cards	32	8%
Other Issues	45	12%

Q20: Percentage That Said They Have Bought a New Mobile Phone, Because They Believed It Was to Expensive to Repair The Old One	Number of Respondents (201)	Percentage (%)
Yes	129	64%
No	72	36%

Q21: Responses to the Possibility of Leasing a Mobile Phone	**Number of Respondents (All)**	**Percentage (%)**	**Summed**
Yes, I Could Very Well See My Self Leasing As Long As It Fits My Normal Monthly Expenses	108	37%	
Yes, But It Very Much Depends On the Extra Service Features That I Get	44	15%	52% - Yes
No, Not As Long As I Don't Have a Clear Overview Of the Costs & Benefits	75	26%	
No, Under No Circumstances	40	14%	40% - no
I Don't Know	23	8%	

Q22: People Who Believe They Get the Right Information About Environmental, and Social Issues When Buying a New Mobile Phone	Number of Respondents (283)	Percentage (%)
Yes	15	5%
No	226	80%
I Don't know	42	15%
	283	

Q23: People Who Would Consider One Product From Another If Rightful Information Was Available Today	Number of Respondents (287)	Percentage (%)
Yes	231	81%
No	12	4%
I Don't Know	44	15%

Q24: Preferred Way To Get Extra Information About The Environmental, Social & Health Profile on The Product at Hand	Number of Entries (706)	Percentage (%)
Directly on the Retailers Home Page/Webshop	175	25%
On the Home Page Of The Producer (OEM)	82	12%
As Part of the Product Display at the Retail Store	171	24%
As a Seperate Printet/Electronic Document at Retail Store/Webshop	79	11%
By The Use of Sustainbility Labels	150	21%
By Oral Query	49	7%

5B. Interviews

As described in section 2.5.3 the interviews for this study were targeted to cover a specific area of interest, this including: the present WEEE-system in Europe and Denmark (DPA-system), the collection system from a CROs point of view (El-retur), the pre-processing step (DCR-Environment) and the end processing step (Umicore).

Interviews is found on attached CD:

- Interview with '*Simon Rasmussen'* on 21st of January 2013. (44 min.)
- Interview with '*Johnny Bøvig'* on 5th of April 2013. (64 min.)
- Interview with '*Henrik Jacobsen'* on 8th of April, 2013. (43 min.)
- Interview with *'Christian Hagelüken'* on 16th of April 2013. (37 min.)

Interview guides were prepared for each interview and as an example; the guide used for Christian Hageüken is showed on the next page:

1. Which fractions do Umicore receives of WEEE (whole devices/appliances or e.g. separated PCB's, Microchips and so forth) – or how specified are they before entering the processing phase *(how much pre-processing or "manual/mechanical dismantling" takes place before you receive it)*

2. Likewise - How much pre-processing (separation, dismantling and fragmenting) do you have to carry out at your facilities before feeding the batch in to the metallurgy/refining processing? *(e.g. In your article on "recycling electronic scrap" from 2006, PCB's are shredded separately)*

3. How much are the total costs of your manual/technical dismantling pre-processing before smelting and refining? (e.g. ca. % pr. Ton/of high tech e-scrap)

4. What product-design features of ICT/EEE would be desirable in the future, minimising costs and optimizing high recovery of all metal fractions (Base, Precious and Special metals)?

"Please list and describe" (e.g. easier separation of components and parts (efficient dismantling), standardisation of metal content, labelling of content (metal groups/ hazardous substances), color codes, standardised assembly-screws, level of source separation, standardised content of alloys and so forth)

5. According to your article from 2010, the economic incentives of PGM's and Cu determine which metals are recovered first – minor metals are lost in sludge or by entering wrong metallurgical phases of major groups such as Fe or Al. Do you choose some specific metals to process from an e-waste batch or can't you get multiple minor metals at the same time from the same e-waste batch no matter what?

(How much manual dismantling into detailed sorting of final feed-in batches would improve the quantity and quality on metal returns?)

6. What metals and minerals *can't* be recovered today due to complex product components and why? In your articles, you talk of minor-metal loss due to low volume in products (occurring on ppm level), thus becoming impurities in other metal products or ending in sludge

7. How big of a problem do you see hazardous substances content in e-scrap is, for efficient and the final recycling of materials? *(Where do you see problems around hazardous substances in the recycling phase)*

8. Is it possible to make specified contracts with e.g. CRO's or OEM's on processing of WEEE send to your facility? If collected e-waste from e.g. deposit- & refund systems should give incitements for producers to innovate design and thereby upgrade the total recycling of embedded metals in WEEE, they assumable would like to cooperate with recyclers by giving suppliers the ability to transfer secondary metals from recycling companies as new input for the production of new components/products. "They probably will not optimize product designs, if the efficiency gain in total output also benefits competitors or other industries". Is it possible to establish hedging or customised service contracts with end-processors on certain metals and hereafter cooperate on knowledge and value transfer between stakeholders in End-of-Life and Design and Production phases?

In relation to the customised operations Umicore carries out with other stakeholders, described here (Hagelüken, 2006: 158) "Recycling Electronic Scrap at Umicore's Integrated Smelter and Precious Metals Refinery"