INTRODUCTION

Since the beginning of society, availability of natural resources has played a key role in the development of human activities. More minerals meant more tools, increased technology and state of the art weaponry, which allowed the advancement of large-scale societies, exploration, conquest and colonization (Diamond, 1999). With the two World Wars and the expansion of mass military, aircraft and navy in all European countries, Russia and the U.S.A., the demand for resources grew exponentially (Kennedy, 1987). However, it was only after 1945 with the reconstruction of Europe and the development of information technology, along with the fast-paced development of Asian countries, that the demand for natural resources, metals in particular, skyrocketed like never before in human history.

"*Over the four decades an increasing specialization of countries with regard to natural resource extraction for trade has emerged...*"

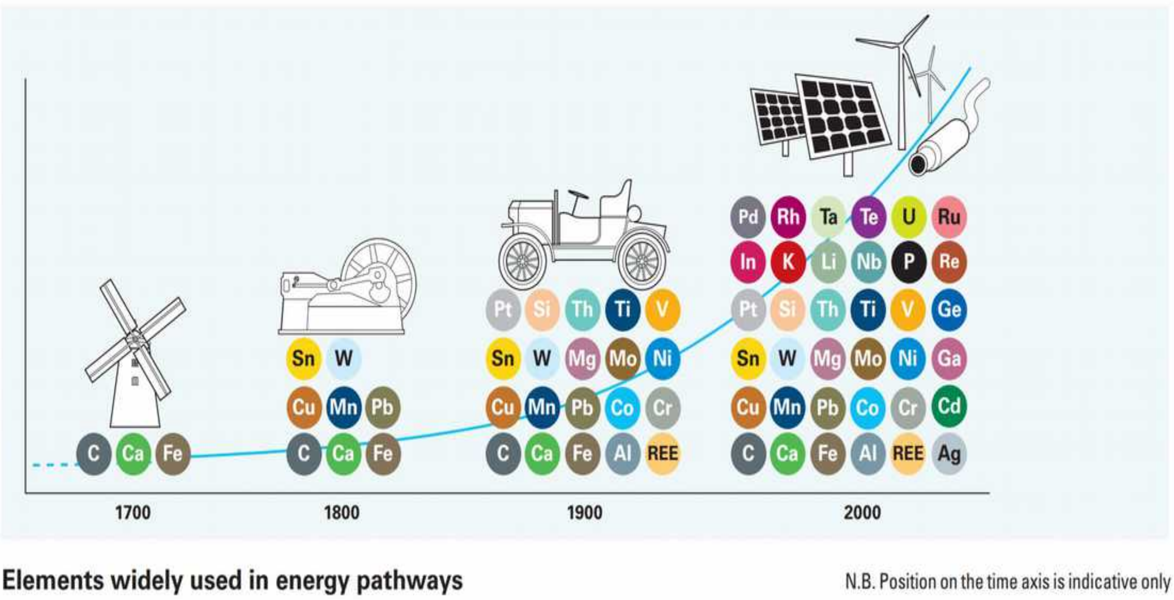
(UNEP, 2016, p.49)

Due to the growing demand of minerals and metals, mining technologies have become essential in supporting growth. In fact, superficial deposits and easily accessible veins have already been intensively exploited throughout history. Hence, the quest for raw materials is leading to the exploration of new deposits even if they are harder to access and more expensive to extract. Nevertheless, thanks to technological development, extraction activities are overall increasing worldwide (UNEP, 2016).

While mining may be essential to human activities and has often been a driver for the settlement and progress of populations, the social impact of the extractive industry is not always clear. While newly found rich ores have often attracted mass migration leading to human settlements, it has also been recorded that, once the vein was depleted, the mining towns were soon abandoned (Richards, 2009). Moreover, indigenous populations living on mineral rich lands, not directly interested in the mining industry, have often had to deal with different circumstances connected to the extractive industry (Alì, 2009): foreign investment on one side, rise in prices and local development on the other, not to mention the environmental and health hazards connected to mining activities, such as accidental spillings and leakages of leaching chemicals.

In many cases, the societal impacts of aggressive mining have generated disputes and tensions within local communities as well as at National and International scales. This tight connection between the presence of extractive industries and abrupt social transformation has lead to think of the presence of natural resources in one territory, more of a burden than a fortune: the *Resource Curse*, as eloquently defined by Jeremy P. Richards in *Mining, Society and a Sustainable World*. Thus, the role of mining in developing economies is somewhat controversial. In fact, the correlation between the development of the extractive industry and local societal growth is often hard to establish and can, in some cases, be actually detrimental to the very existence of native populations. Whether mining activities promote development or widen the gap between rich and poor is mostly a matter of politics (Richards, 2009). Studies show how corruption, rent-seeking and labor exploitation brought by mining activities in one region, are often the main cause for increasing poverty and social distress in developing countries in particular.

Yet, All these metals and minerals we extract from the earth's crust at increasing rates are fundamental for the development of new and “clean” technologies. While before and soon after the World Wars machinery, weapons, cars and all the devices requiring raw materials, were mainly composed by a mere handful of elements, mostly iron (Fe), Aluminum (Al), Copper (Cu), and a few other, amongst which precious (Au, Ag) and platinum group metals (Pd, Pt, Ir, Rh). With the development of Information Technology, telecommunications and computing devices, the number of natural elements required for production has also risen exponentially.



(Table1, elements widely used in energy pathways. Zepf et al., 2014)

For instance, an auto vehicle in 1937 was composed by 20 – 30 elements, while an electric car produced in 2012 counts more than 90 elements on the periodic table. (Zepf et al, 2014) Table 1, well describes the evolution of contents in technological products and the elements widely used in today's energy pathways (Table 1, Zepf et al., 2014).

Eventually all products come to an end, and in the contemporary world things are designed to only last a certain amount of time: this practice is called “planned obsolescence.” In fact, in order to maintain demand and therefore ensure a continuous business, producers often choose to design the life expectancy of their products so that, at a certain point, the consumer will have to buy a new device (Bulow, 1986).

The new WEEE Directive 2012/19/EU became effective on 14 February 2014 (www.ec.europa.eu). This directive allows member countries to implement measures to improve longevity of new products. Nevertheless, since the first appliances were produced, countless amounts of raw materials have been mismanaged at the end-of-life of the commodity. Judging by the level of general awareness over the availability and use of raw materials in everyday objects and the current difficulties in proper management of waste electronics, it is most probable that several thousands of metric tonnes of raw materials, precious and base metals and other elements are now in our landfills. A report by the Countering Waste Illegal Trade (CWIT) project published on August 30th 2015 (www.cwitproject.eu), outlines the current rate of equipment that is estimated to end up in landfills every year. Thus, the European Union is currently financing innovative projects to Re-mine Europe, planning future mines in our former landfills (www.eurelco.org).

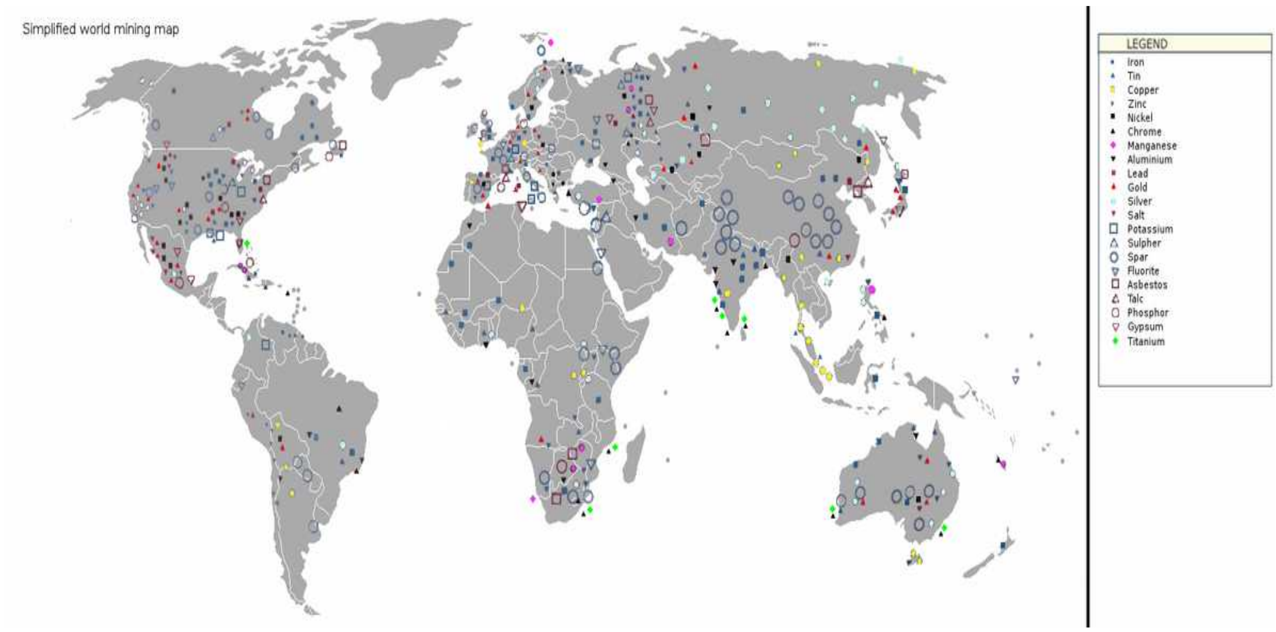
CHAPTER

1

- Mining -

"...mined products pervade all industry and the lives of all civilized people"

(Hartman, 1987).



(Image 1 - Simplified map by KVDP, The map was made using data from the book Kerrod R. *Future Energy and Resources;* Williams L. Collinson, A. *Working with the oceans* . A specific focus has been put on metals, and construction materials, 2009)

Introduction

Mining is the act of extracting valuable minerals or other geological materials from the earth from what is referred to as an orebody, lode, vein, seam, or reef, which forms the mineralized package of economic interest to the miner. Ores recovered from mining are typically metals. Other types of extraction sites for the extraction of rocks and stones are usually referred to as quarries. Mining in a wider sense includes extraction of any resource such as petroleum, natural gas, or even water and as such is required to obtain any material that cannot be grown through agricultural processes, or created artificially in a laboratory or factory. Nevertheless, this research will focus solely on precious and technology metal extraction in particular.

(Image 2 – Satellite view of the Molycorp Mountain Pass rare earth facility in California's Mojave Desert. Google Maps)

Mining of stones and metals has been a human activity since prehistorical times. Modern mining processes involve prospecting for ore bodies, analysis of the profit potential of a proposed mine, extraction of the desired materials, and final reclamation of the land after the mine is closed (Kalvig, 2014). Mining operations forcefully have somewhat of a negative environmental impact, both during the mining activity as well as after the mine has closed. Hence, most of the world's nations have passed regulations to decrease the impact of mining. Moreover, also worker safety has long been a concern and modern practices and procedures have significantly improved safety in mines.

1.2 Traditional Mining Methods

Traditional mining was developed in ancient times and basically consists in digging up parts of the Earth's crust where certain materials are contained and then process the rock to extract the elements of interest through thermal and chemical processes. Therefore, mining is one of the most energy intensive human activities and the use of chemicals makes it all the more dangerous.

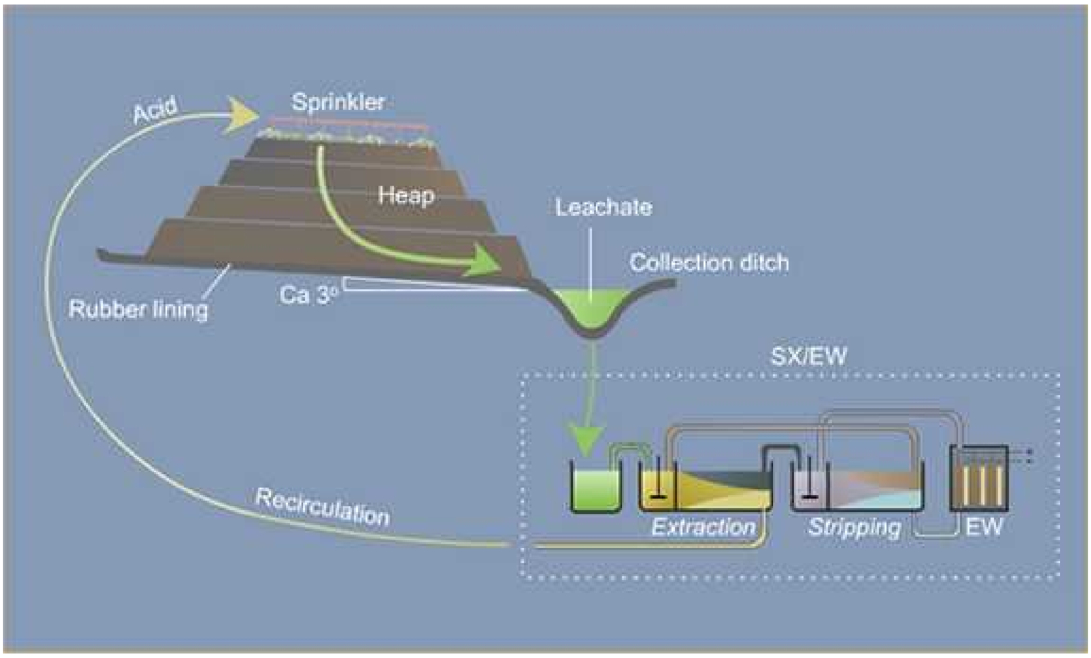
a) Mercury Amalgamate.

The mercury amalgamate method consists of using mercury as a solvent to separate valuable metals such as gold and silver from the minerals in which they are embedded. Since mercury is liquid at room temperature it can easily infiltrate the matrix rocks and dissolve the precious metals contained (Image3).

(Image 3 mercury amalgamate 60%Au 40%Hg Telmer, 2009)

While the mercury amalgamate absorbs the surrounding metals it becomes increasingly more solid and, in the presence of gold, it turns to pale yellow. Once the amalgamate reaches saturation it is heated on a stove and the mercury, which has a lower boiling point (356 °C) compared to the other metals in solution, evaporates leaving a precious alloy inside the crucible. This method has long been used in Ancient Roman times and for the Spaniard silver industry in South America during the 17th Century. This process, which was exported to the American colonies in the 1550's by a Sevillian cleric named Bartolomé de Medina, and adapted to the large-scale demands of the New World's mining industries, proved to be revolutionary. For instance, literature reports "The silver mines of the high Andes demanded 5000 quintales (275 tons)" of mercury (Malcom, 2006). Despite this method being very dangerous and exceptionally harmful to human health due to the evaporation of mercury which is released into the atmosphere, it is still used today. Despite safer alternatives and the elimination of mercury use in large-scale mining operations, unfortunately It is still widely used by artisanal and small-scale miners (ASM), often in unsafe and environmentally damaging ways. The United Nations Industrial Development Organization estimates that 1,000 tons of mercury are released into the air, soil, and water each year by this sector (UNIDO, 2007).

b) Heap Leaching

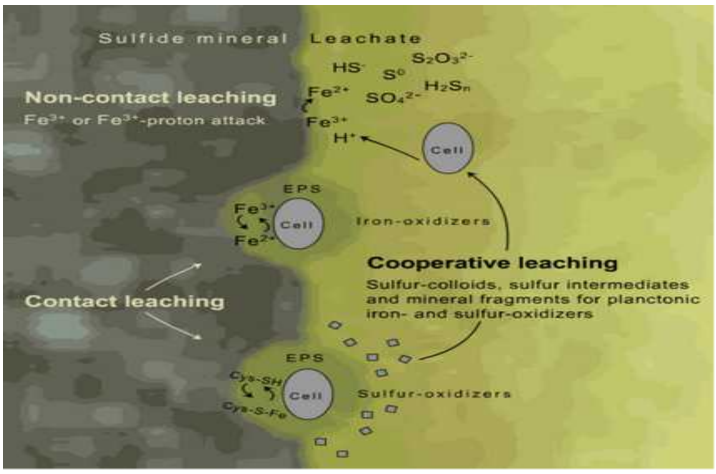


(Image 4 *Heap leaching followed by solvent extraction and electro-winning.* Bauer, 2007)

The heap leaching method is the most widespread and commonly used extraction method among large formal mining operations around the world. Heap leaching basically involves stacking metal-bearing ore into a "heap" on an impermeable pad, the ore is then irrigated for an extended period of time (weeks, months or years) with a chemical solution to dissolve the metals within. By collecting the leachant ("pregnant solution") as it percolates out from the base of the heap, the lecheate is further processed by electro-winning separation or chemical precipitation to retrieve the different metals (Image 4).

Common leaching solutions are a dilute alkaline solution of sodium cyanide which dissolves metals without dissolving many other ore components. Copper, zinc, mercury and iron are commonly extracted this way. This method is highly cost efficient since the investments required are very low and when responsibly managed it is also relatively safe (Kappes, 2002). Heap leaching however is quite pollutant because of evaporation of harmful gases into the atmosphere and can lead to tremendous consequences in cases of leakage or spilling of the leaching chemicals into rivers or underground waters. In recent years, a string of cyanide-related mine accidents has added to environmental and community concerns. The disaster in Romania at Aural Gold Plant is one example. On January 30, 2000, 100.000 cubic meters of cyanide-contaminated waste entered the Tisza River, eventually poisoning the Danube and infecting over 250 miles of rivers in Hungary and Yugoslavia. In reaction to cyanide accidents, communities are beginning to speak out against cyanide leach mining. Most notably, voters in Montana passed an initiative in November 1998 banning cyanide heap-leach mining. The initiative, now state law, prohibits the development of new open-pit cyanide leach mines. This initiative was a response to the dismal track record of open-pit cyanide leach mining in Montana and the failure of the State to adequately regulate such mines. Hence, cyanide leach mining can have a profound impact on the environment, human health and wildlife (Mineral Policy Center, 2000).

c) Bio-mining



(Image 5 *High-Rate Ferric Sulfate Generation and Chalcopyrite Concentrate Leaching by Acidophilic Microorganisms.* Bauer, 2007)

Bio-mining is the process of extracting valuable metals from ores and mine tailings with the assistance of microorganisms. It is a very low capital, low operational cost, and a low energy input process. This technology is also environmentally friendly as it generates minimal amount of pollutants. It has the added benefit of mining low-grade ore and mine tailings. The depletion of high grade ores and the onerous environmental burden inherent in the pyrometallurgical technologies are forcing mining companies to examine alternative extractive procedures.

Bio-mining can undoubtedly provide a green technology solution for exploiting mineral resources. Physical-chemical processes utilized in conventional mining technologies necessitate large amounts of energy for roasting and smelting and produce harmful gaseous emissions such as sulfur dioxide. Bio-mining may help eliminate these problems. Furthermore, the tailings generated by bio-mining operations are less chemically active. The biological activity these tailings support is minimum as they have already been bioleached. The modest nutritional requirements and the irrigation needed to support the selected microbial life in heap or tank reactors are indeed less expensive than the enormous cost associated with pryometallurgical processes (Appanna, 2012). Nevertheless, bio-mining is slower than traditional mining techniques and is not applicable to a wide variety of ores. In addition, this technology has several disadvantages such as the lack of complete control over the conditions, leading to unpredictable or inefficient extraction rates. Production of acid (sulfuric acid) is also a major drawback associated with bioleaching. $CaCO_3$ could be added to neutralize the acid but it generates solid wastes which must be disposed of properly. Sulfate reducing bacteria may also be added to counteract the acid produced by the bioleaching microbes. In 2008, for example, a new venture started operating in Talvivaara, Finland. It was set up as the result of a European research project called BioShale, which showed that bacteria could recover nickel, copper, lead, silver, zinc, cobalt, rhenium, selenium, tin, gold, platinum, palladium and uranium from Europe's extensive but underexploited “black shale” deposits. In Chile, which has 30% of the world's copper deposits, BHP Billiton, a mining giant, has set up two bioleaching operations in the past three years, each aiming at producing around 200,000 tonnes of copper per year. Bioleaching may be slower, but it is also cheaper, making it well-suited for treating ores and mining wastes with low metal concentrations. It is also generally cleaner (http://www.economist.com).

1.3 Sociology

a) Only NIMBY or is there more to it?

NIMBY is a commonly used acronym that stands for: *Not In My Back Yard.* NIMBYism is one of the most complicated and difficult problems to tackle, especially in mining operations. For example, even during the economic crisis in Greece, the reactions against mining remained intense, despite the economic opportunities offered by the industry. Lack of information, conflict of interests and other commonly used justifications cannot adequately explain the NIMBY phenomenon and do not provide the grounds for effective solutions.

Mining has a substantial influence on several parts of society, since this industry provides the metals and minerals used in the production of everyday commodities. In many countries and regions around the world, mining also has a substantial impact and importance both for the local socio-economic development as well as for National economic stability. Benefits of mining can arise both from direct financial investments, generating employment opportunities; and from capital investments in subcontractors and their services. In addition, mining activities usually have a, so called, multiplier effect on local business development in connection to the mine. The positive economic effects of a mine can also stimulate the development of local and regional health care and educational services as well as community cultural activities. The many positive benefits derived from mining often lead to a situation where local communities are as reliant on the mining company as the mining company is on the local community and its resources.

Society cannot thrive without mining and mining cannot exist without social consent. Nevertheless, in contrast with the many positive effects of mining, extractive practices are often associated with the environmental costs and the adverse effects they have on society. Although mining is a temporary land user, in many cases the impact of mining appears to be permanent, during and after mining operations. Water pollution, destruction of the land, noise, dust, vibrations from the blasting, leakages from refineries and the release of toxic substances are some of the common downfalls mining has on the environment. Furthermore, mining accidents such as ruptured dams and chemical spillage can have dramatic effects on plants, animals and neighboring communities. Also, the discovery of new deposits can lead to many negative effects on local and indigenous populations.

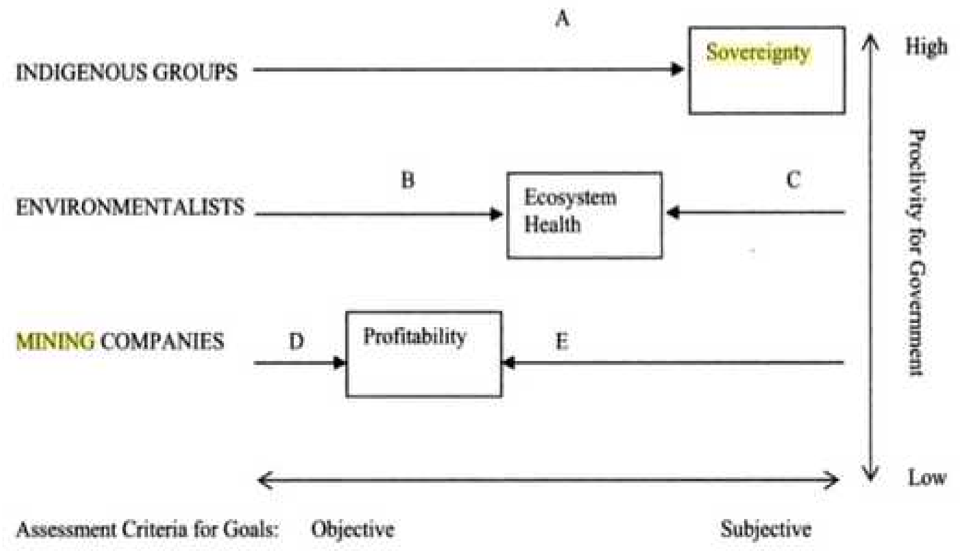
The wide array of both positive and negative impacts of mining has led to continuous confrontation between citizen groups, government agencies and the mining industry concerning the allocation of costs and benefits in society. As a result, nowadays mining suffers from the NIMBY syndrome more than ever: "you can mine everywhere, but *Not in My Back Yard*." This phenomenon occurs largely worldwide. Even in economically weak regions, when it comes to opening a mine, government expropriation in favor of development appears to be impossible and perceived as unfair by the people. The challenge of dealing with NIMBYism in resource extraction activities in particular, is greater than in other controversial activities also because mining must occur where there are natural deposits. Therefore, there is no choice on the location of a mine as they cannot be relocated. Since human activities and technology are highly dependent on mined minerals it is necessary to draw a road map for the social acceptance of mining (Menegaki, Kaliampakos, 2014).

Opposition to proposed land uses is therefore often crudely summarized as selfish or ignorant NIMBYism. However, empirical studies of the reasons people give for their opposition to proposed land uses tend to reveal a wide range of motivations and explanations. For instance, Kemp's (1990) study on local responses to UK Nirex Ltd's proposal for the disposal of low and intermediate level radioactive waste found that objectors drew on a range of values and concerns as the bases for their complaints. In their analysis of survey data from citizens facing the decision whether or not to site a hazardous waste incinerator in their community, Hunter and Leyden (1995) found little evidence of people concerned about property values. They conclude instead that opposition is related rather to lack of trust in the government, their fear for health hazards and other ideological or demographic factors. To a large extent the NIMBY label is grounded in rational choice theory. There is indeed a vast array of empirical work suggesting that self interest may be only one of the factors that influence public opinion and political behavior. In addition to self interest, there are an array of other motivations such as fairness, sympathy, commitment, citizen duty, morality and long standing ideological beliefs. Opponents will usually provide broader explanations for their position in order to avoid being simply labeled NIMBY. Therefore, project developers and other industry proponents must place more emphasis on addressing the concerns that citizens actually express (Burningham, Barnett, Thrush, 2006).

b) Mining and sovereignty

*"We must move away from the sterile question of whether efforts to cope with ecological problems erode or bolster some refined conception of sovereignty to the more intere*sting *question of how such efforts lead to e reconfiguration of political space"* (Liftin, 1998, p. 2).

Mining has broad effects on the environment and on populations living in the area. As mentioned previously, the issues are much more complex and delicate than a simple NIMBY phenomenon. Indigenous communities resist because of a fundamental disconnection between the goals of the various stakeholders rather than differences in perceptions of the actual environmental impact of mining. Misunderstandings often exacerbate divisions, thus preventing consensus among communities. It is however possible to move beyond zero-sum views of power and focus on negotiating specific needs and resources among the different stakeholders. Although this process requires a high degree of interdependence and trust, it will eventually prove to be mutually beneficial to all parties (Alì, 2009).



(Table 2 *Indigenous groups sovereignty, Environmentalist groups and Mining companies*. Ali, 2009 p.171)

To better understand the interest of the various stakeholders in a typical mining operation we can refer to Table 2 and the research conducted by Saleem H. Ali: *Mining, the Environment and Indigenous Development Conflicts.* The rectangular boxes positioned horizontally along a continuum of assessment criteria, ranging from objective to subjective, represent the goals of each stakeholder. The terms “objective” and “subjective” indicate the degree to which the assessment criteria can have multiple interpretations.

The primary goal of mining companies is profitability. This is calculated in realist currency and thus is nearest to the objective end of the spectrum. However, there are some important subjective issues as well regarding how to account for one's profits. Therefore the rectangle representing mining companies' goals is not at the extreme end of the range. Environmental goals instead rely on objective criteria such as scientific studies but also have an important normative dimension based on judgments about consumerism and social justice, hence they are somewhere in the middle. Finally, the primary goal of indigenous groups is sovereignty. This can be a highly subjective assessment criteria and is therefore on the opposite end of the spectrum. The most interesting attribute of this diagram are the arrows that depict predominant strategies for reaching the desired goals. The length of the arrow indicates the general prevalence of the strategy and the direction indicates the part o the spectrum toward which that particular strategy is inclined.

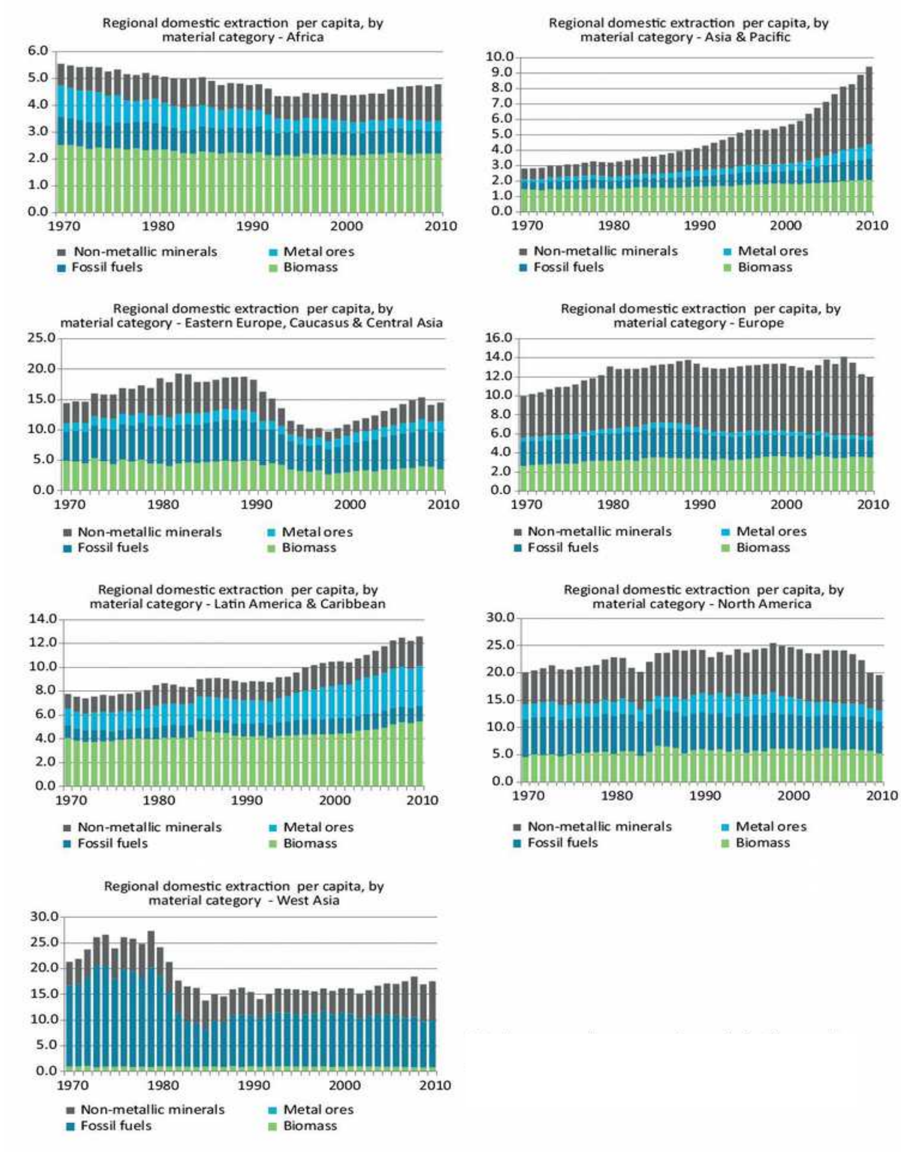
Arrow A indicates the fundamental desire for indigenous groups to gain sovereignty. There is only one arrow because achieving sovereignty is not based on a balance between different approaches.

Arrow B has the same direction as A and refers to those issue areas whose strategic use can indeed lead to sovereignty as well as ecosystem health. This arrow also embodies the normative attributes of environmentalism that advocate small-scale economies (Schumacher, 1973), which are often congruent with native aspirations for sovereignty. Nevertheless, the goal of ecosystem health is situated in a place that also requires certain actions that undermine native sovereignty (Arrow C). These are the issue areas that can lead to tensions between natives and non-natives.

Arrow D, instead, reflects those practices in the mining industry that support indigenous sovereignty through employment and self-sufficiency and that can be effectively harnessed. However, the profitability goal of mining companies is often directly in opposition with the sovereignty vector A. This is related most acutely to the issues of royalties and land claims. In fact, even the most acclaimed indigenous mining agreements bear a history of litigation and an initial attempt on behalf of the mining companies to get title to the property.

Along the vertical dimension there is the “proclivity for government involvement.” The government is in fact a stakeholder with multiple goals that cross both dimensions. The vertical scale is meant to indicate the degree of government involvement each of the three stakeholders prefers. Indigenous groups are at the top because they aspire to achieving their own sovereignty and there is an underlying love-hate relationship with federal governments in a continuous struggle between self-determination and termination. Environmental groups certainly want government involvement at some level to regulate pollution, but they are also skeptical about centralized authority and are therefore in the middle. Mining companies have the least proclivity for government involvement, as is to be expected of a private corporation; hence they are at the bottom of the spectrum. However, in terms of power dynamics, they are clearly not at the bottom and power is a central locus of theory development in this context (Alì, 2009).

1.4 Resource availability and growth



(Table 3 *Regional domestic extraction per capita by material category.* UNEP, 2016, p. 54)

Different parts of the world are endowed with different natural resources and some resources are more common than others, which are only available in limited places. Past economic development and the history of natural resource exploitation have put different world regions on different trajectories resulting in different outcomes for material flows and material efficiency. While global material extraction tripled between 1970 and 2010, this growth was overwhelmingly driven by increasing domestic extraction in the Asia-Pacific region, which increased more than five-fold in just 40 years, at a staggering annual rate of nearly 4.8%. Europe and North America instead experienced sharp declines in their global share of material extraction and so did Eastern Europe, Caucasus and Central Asia (EECCA) whose fall in share was most pronounced (Table 3). Latin America, West Asia and Africa all saw growth in total Domestic Extraction with peaks greater than 100%, featuring annual growth rates of 3.1%, 2.9% and 2.5% respectively. Asia-Pacific region's per capita extractions of metal ores also grew more than threefold (UNEP, 2016).

Conclusions

The key driver that has enabled supply to keep up with demand in the past, has actually been technological progress in exploring, mining and processing mineral raw materials. Current reserves represent only a small portion of the mineral resources remaining in the earth's crust (Table 4). Additional reserves are continually identified at existing mines as well as in previously unknown deposits. Such deposits may occur in frontier areas, such as the seafloor, deserts, extreme depths, the arctic region or even in terrains previously regarded as unprospective. Completely new deposits may be identified, thus opening up new exploration potential. For example, the class of deposits known as epithermal precious and base metal deposits, which were unknown before the 1970s, now strongly contribute to global precious metal reserves. Even the discovery of a single new deposit may have a major impact on global reserves and allow the production of a large number of commodities. For example, the Bayan Obo deposits account for the majority of China's 31% share of the world's Rare Earths reserves. It is also significant to note that in most parts of the world, exploration drilling rarely exceeds 200 m in depth, although it may extend up to 500 m in some established mining districts. Moreover, most mineral deposits are close to the surface, with the deepest open-pit mine less than one kilometer deep. The deepest underground mine descends about 4 km into the Earth's crust. Given that the continental crust averages about 35 km in thickness it is clear that there is enormous potential for the discovery of deep mineral deposits.

	Recoverable reserve	Global extraction in 2010	Years of available reserve at 2010 extraction level
Oil	233 billion tonnes[1]	3,573 million tonnes	65
Coal (bituminous and lignite)	1,318 billion tonnes[1]	7,025 million tonnes	188
Natural gas	176 billion tonnes[1]	2,609 million tonnes	67
Iron ore	190 billion tonnes[2]	2,634 million tonnes	72
Copper ore	100 billion tonnes[2]	1,877 million tonnes	53
Bauxite and Alumina	28 billion tonnes[2]	226 million tonnes	124

Sources:

[1] World Energy Council (2015) https://www.worldenergy.org/data/resources/

[2] USGS Mineral commodity summaries 2015a

(Table 4 Recoverable reserves of key commodities UNEP, 2016, p. 35)

New developments in exploration and mining technology and their application in new terrains and at greater depths are therefore critical for ensuring the technical availability of mineral raw materials. In addition to new discoveries, technological advances in the mineral commodity life cycle (processing, manufacturing, recycling and substitution) also have an important role. More efficient processing methods enable improved yields on by-products and can thus have a highly significant impact on future availability of key technology metals such as gallium or germanium. In addition, more efficient use of resources and recycling can be very effective in supplementing existing reserves. However, mining will continue to be the main basis of supply in the future because of the structural growth of usages, growth of population and global demand. Consequently, it is most important to strengthen the geological knowledge base to locate new deposits as well as frame conditions for efficient recycling and global political and economic frameworks, under which the extractive sector operates, and thus to ensure it performs effectively and in a sustainable manner (European Commission, 2010).

CHAPTER
2

- Urban Mining-

"Because, if a thing has parts, the whole thing must be the same as all the parts."

(Plato, 369 BC)

Introduction

Whether or not resources are thinning and technological development will support growth infinitely, it is senseless to keep on squandering useful materials and poisoning our Earth in the process. This chapter will hence investigate the estimated amounts of waste produced worldwide every year. Focus will be on appraised values of raw material flows within waste streams. This section will then further discuss the opportunities recycling offers in creating sustainable material inflows in the production process, focusing on "technology metals" in particular. High collection rates along with reuse and safe recycling have great potential for generating employment. The International Labor Organization, for instance, released an assessment report in 2012 regarding the global impact of e-waste.

Among others, widespread education of new generations in particular is identifird as playing a key role in modeling and managing future waste streams (Ludgren, 2012).

Take back systems have been and are currently being implemented at various scales worldwide (Wiedmer et al., 2005). However, there is still a considerable gap between EEE input on the market and Waste Electric and Electronic Equipment (WEEE) recovered yearly (Interpol, 2015) and many of the take-back practices: “one-on-one” or “one-on-none” are not economically convenient for the producer nor for the retailer (Stevels et al., 1999). In addition, as the population becomes more aware of the precious and base metal content of their technology they will eventually become more reluctant to return their old devices and will instead collect e-waste in their cellar or attic, waiting for the market to appraise their waste electronics and possibly have a return on their purchase.

Therefore, investigating the gray areas of the undefined boundary that separates useful objects from waste, can offer creative solutions, able to attract consumers as “producers of waste” into addressing their purchases as well as their waste towards more “responsible” trade. This is key to preventing unlawful trafficking, processing and dumping of e-waste with all the environmental and health hazards that this may imply (Wiedmer et al., 2005). Thus, the loop would be closed allowing the creation of new jobs and innovative professional profiles in the field of Circular Economy and secondary resource markets, e-waste in particular.

2.1 The nature of e-waste

“E-waste is a term used to cover all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of reuse” (Step-Initiative, 2014). E-waste, or waste electrical and electronic equipment (WEEE), is a complex and fast-growing waste stream. The composition of which is made up of a vast variety of materials, including toxic elements as well as valuables such as gold, silver, copper and many other “technology metals”. Yet, the amount of valuable materials varies significantly from product to product.

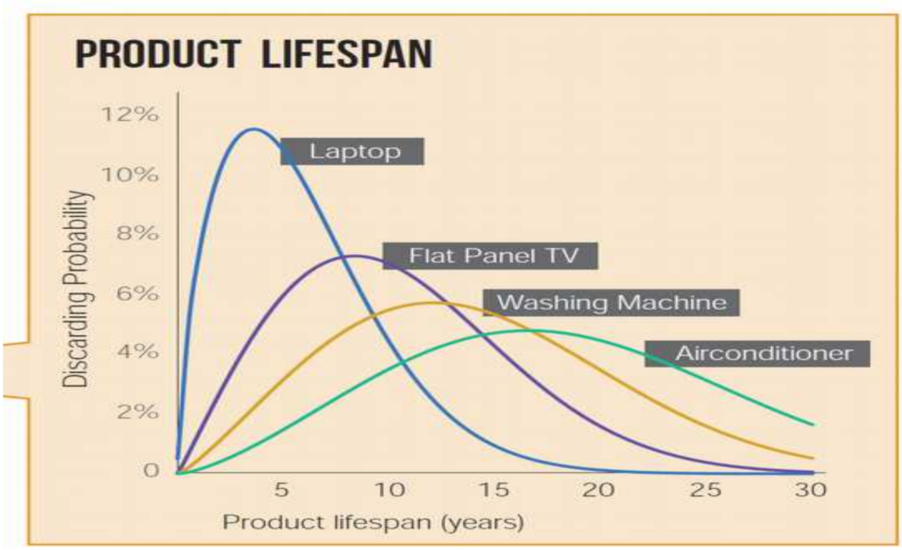
Rapid product innovation, miniaturization and planned obsolescence, especially for information and communication technology (ICT), are fueling this unprecedented increase of e-waste. From past assessments, it is still unclear how much e-waste is generated and how much of this is actually collected in each country or region. Available data are either out-dated or hardly useful for cross-country comparisons. Therefore, e-waste is an emerging and fast-growing waste stream with complex characteristics. In fact, the increasing amount of WEEE is generating imposing challenges to waste management systems in both developed and developing countries. Rapid technology innovation and ever-shortening product lifespans are among the major factors contributing to this problem. (Baldé et al, 2014)

2.2 Prospects of Urban Mining

If we were to draw a “periodic table of recycle-ability,” only copper, used in pure form as a conductor of electricity and heat; lead,used in batteries and five precious metals: gold, silver, platinum, palladium, and rhodium, are considered to be easily and efficiently recyclable. Other metals instead, found predominantly in multicomponent alloys, such as 0.1 percent niobium in high-strength steel, are quite difficult, sometimes impossible, to recover. Recovering metals from complex material mixes and those used as “spice metals” such as the tantalum found in capacitors, is similarly challenging. Since metals in alloys and assemblages are commonly used in very small amounts, the separation process is extremely complex and yields are very low and economically unsatisfying (Meskers, 2015). Based on the quantity of e-waste and the resource potential of recyclable materials contained within this particular kind of waste, the process of collecting and selecting the valuable parts is commonly referred to as the “urban mine,” while the hazardous materials contained in e-waste are commonly referred to as the “toxic mine.” The intrinsic material value of global e-waste was estimated around 48 billion euro in 2014. The material value is dominated by gold, copper, silver and plastic contents. On the downside, however, the annual supply of toxins from e-waste includes 2.2 Mt of lead glass, 0.3 Mt of batteries and 4 kilo tonnes (kt) of ozone-depleting substances (CFCs). Only 6.5 Mt of the 41.8 Mt of e-waste are documented and recycled with the highest standards. Thus, the full potential of e-waste collection and treatment has not yet been completely explored (Baldé et al, 2014).

2.3 Green design and planned obsolescence

The staggering amounts of e-waste generated every year call for deeper investigation into the reasons *why* electronic devices are thrown away at such impressive rates. Some devices were well-built, but due to technological development and wear-and-tear they have just become obsolete or have broken down for good and must be replaced. Other devices, instead, were poorly designed and produced with cheap quality materials and therefore have an intrinsic short life expectancy. Yet, other electronics, are subject to a thorough study with the intent of carefully gauging the life of the object on the basis of fashion and incompatible upgrades in order to have the consumer continuously buy new products still maintaining enough confidence in the producer.



(Table 5 *Average lifespan of particular Electric and Electronic Equipment commonly found in households around the world.* Graph developed by *UNU – Global e-Waste monitor* Baldé et al., 2014)

Rapid advancement of technology forces the market to continuously upgrade and reissue more powerful products. Nevertheless, due to the intrinsic properties of the materials used in computing technology, there are also some limits such as 3GHz processors, which are bound to the physical properties of Silicon (Si) (Zheng et al., 2013). Therefore, it is likely that the ICT production oligopoly is currently colluding on pacing product output in order to maximize profits within the technological limits. Hence, most of the obsolescence found in ICT is planned in order to push the aggregate demand and maximize profits rather than presenting outstanding innovative breakthroughs (Bulow, 1986).

Future scientific developments will require use of substitutive mediums to overcome the physical limitations of silicon and this will, with all certainty, result in the use of other elements, such as germanium, gallium arsenide or graphene (Zheng et al., 2013). The increasing demand for "technology metals" will forcefully require mining. However, given the 3GHz technological constraint, increased consumer awareness will eventually lead to more perfectly informed markets, forcing oligopolistic producers to collude on preferring durability and rent over sale (Bulow, 1986). This happens because, knowing their ICT has limits, consumers will opt for marginal choices demanding to maximize durability, interchangeability and upgrade-ability of their purchase. Pilot projects such as *Arduino* and *Raspberry* are a few examples of where the future market is heading.

As this saturation process takes place, there will be an increasing need for new constraints in product design and engineering processes, factoring in the end-of-life cycle and improving durability, repair-ability, upgrade-ability and disassemble-ability of products. Research & Development (R&D) is already generating a wide array of new jobs all throughout the economic system from cradle to cradle. In addition, new business models shall develop offering new solutions for a wasteless future in the 4th industrial revolution (Mavropoulos, 2010).

Although mechanical separation is a widely used technique that allows to process huge amounts of waste in relatively short time, these methods require big and expensive machinery. Moreover, the precision of output varies between 70 to 80% accuracy with state-of-the-art shredders and sifters. The best way yet to disassemble e-waste is by hand (Davis et al, 2003). Nevertheless, manual operations are a time consuming process that requires concentration and a certain degree of precision and patience, therefore calling for qualified and trained operators (Theurer, 2010). Companies should work on designing easily reparable and disassemble-friendly products, in order to ease operations downstream, both for in-house take-back operation as well as for other formal and informal collectors and disassemblers. Setting aside the time factor, such manual operations can also be carried out by people with certain mental and/or physical disabilities and can be used as entertaining activities for deviant social categories in rehabilitation situations, inmates, as well as for migrants. Organization of e-waste related workfare programs could also play a key role in mitigating and eradicating extreme poverty. For example the “100 day programs” have proven to be quite effective in construction works in India (Migheli, 2016). A report by the International Labour Organization (ILO), in particular, states that one of the best ways to prevent bad practices and integrate the informal sector into semi-formal and formal systems is to promote and foster cooperatives (Ludgren, 2012).

Currently treated e-waste usually dates back 10-30 years and most of the appliances dismissed are from the late 1980's and 1990's. However, future technologies will change in material content and complexity while size will be increasingly reduced. Thus, also the contents and composition of future e-waste will change according to the developments in technology.

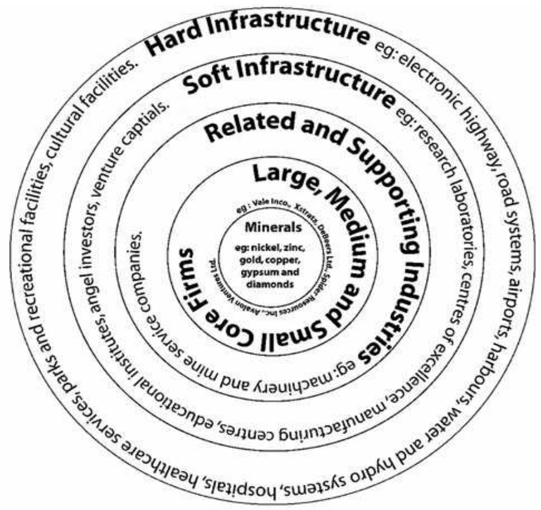
2.4 E-waste geopolitics

This paragraph investigates the relations between e-waste and the territory. It will not take into consideration global EEE and WEEE flows, which will be further investigated in the next chapter. It will concentrate instead on the relationship between territory and collection. As a matter of fact, the main issue regarding e-waste processing is the collection rate (Hagelüken, Meskers, 2015). The capillary distribution of technological products around the planet poses major challenges under the logistic and efficiency point of view in gathering and correctly addressing e-waste streams. Comparing mining to “urban mining,” they appear as opposite: regular rock mining must occur where the natural deposits are, whereas e-waste collection and treatment has virtually no vertical constraint with the territory, except for large smelting and refining facilities, which are currently the only industries able to safely extract valuable materials from the mix of components in which they are embedded.

(Image 6 *Legami verticali e orizzontali* Adaptation from Beccardino M. 2015 Political Geography, Lesson 0)

e-waste instead, virtually features distinctive horizontal constraints, from collection to trans-boundary movements. This reduces the likelihood of stumbling into the so called *Dutch Disease* (Richards, 2009) which is connected to the exhaustion of a particular ore or industry in a particular territory. E-waste, in fact, does not present the typical symptoms of this disease (sudden development, rise in prices, labor migration) nor is it likely to do so in the near future, unless, and it is quite improbable, electric and electronic products quit being produced altogether. Current trends, in fact, show exactly the opposite: production and use of technology is increasing all over the world also in the most remote places (rural Africa, Asia and South America). Life span of products is shortening and consequently also e-waste is growing and is prospected to grow in the next years with ever more intensity and capillarity.

Table 6 shows a traditional mining industry cluster (Richards, 2009). The urban mining cluster could be described inversely. While in traditional mining the resource is fixed, in urban mining the resource is displaced in many small fractions, which are spread and embedded inside consumer goods. Safe urban mining requires big investments and certified smelters and processing plants. Nevertheless, many goods may have a second market value and some steps of the disassembly process can be safely done at a micro and artisanal level, thus separating materials before collection and take-back. Hence, we can imagine the scheme of Urban Mining looking exactly the opposite of what is described in table 6: The small and micro level scale is on the outside, gathering, selecting, disassembling and refurbishing. Moving towards the inside, we find larger specialized firms processing the selected parts. Also the transportation process would largely benefit from pre-selection, reducing CO_2 emissions and bureaucratic procedures. In the center there are the large refineries, ports and transportation docks representing the knots of interconnecting hubs in this fretwork of horizontal relationships (Image 6). These hubs are the hard infrastructure required to safely smelt the unconventional “e-waste ore.”



Mineral industry cluster—key building blocks. Diagram design adapted from Cluster Navigator Ltd., with content developed by Ontario Ministry of Northern Development and Mines

(Table 6 *The Mineral Industry Cluster* Richards, 2009, p. 191)

As described in Table 7, collection plays a major role in the e-waste recycling industry. Collection and disassembly in fact represent the largest part of the industry in terms of number of actors and “employees.” This is confirmed by the number of firms involved in this part of the process, which requires minimum investments and therefore attracts many operators. As the waste is selected and moves into pre-processing and smelting operations the number of firms shrinks considerably due to the huge investments required for machinery and smelting plants able to operate in safe and environmentally sustainable manners (Hagelüken, 2015).

(Table 7 Recovery of technology metals from recycling circuit boards. Hagelüken and Meskers, 2015)

ILO and UNEP studies also confirm that e-waste can play a fundamental role in mitigating and eradicating extreme poverty in its functions of promoting secondary markets and recovery of valuable materials. However, it is urgent to train, teach and educate operators and professionals in order to develop systematic procedures, easy to implement at small and micro levels. Operating simultaneously on different levels and allowing small actors to operate in safety can prevent the release of toxic elements into the environment, protect human health and ecosystems, still remaining sufficiently profitable to increase workers' living standards. These systems can be different, flexible and can be implemented both in developed and developing countries with slight variations accordingly.

2.5 Worldwide disposal of e-waste

Around 41.8 Mt of e-waste were generated globally in 2014 alone. Approximately 4 billion people were covered by national e-waste legislation regarding e-waste good practices. However, legislation is not necessarily supported by effective law enforcement and often regulations “stay on paper” only.

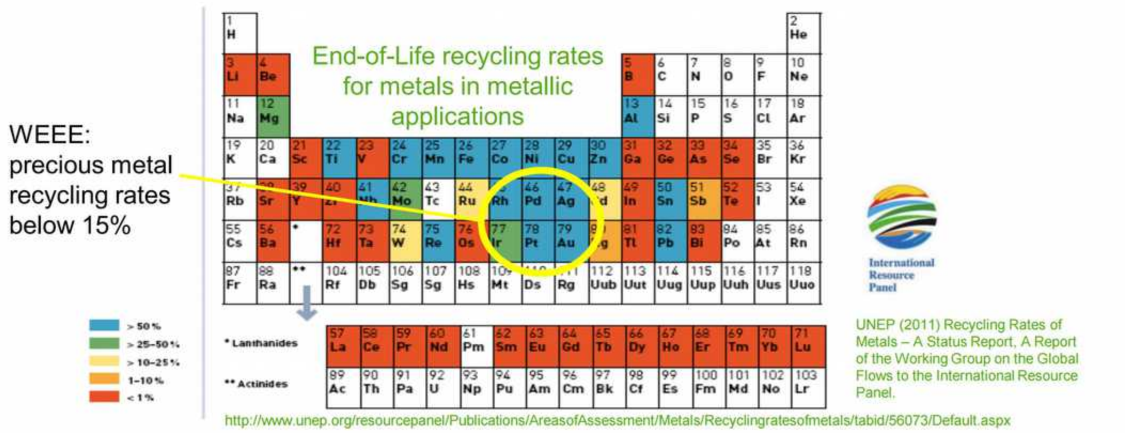
Driven by these national laws, around 6.5 Mt of e-waste were formally treated by national take-back systems. Yet, not all e-waste laws have the same scope. It is estimated that in the 28 EU Member States alone, up to 0.7 Mega Tonnes of e-waste has been thrown into regular waste bins every year. Yet, the actual amount of e-waste that is disposed of in waste bins remains unknown in other regions. The quantity of e-waste collected outside formal take-back systems cannot be systematically documented, therefore, there is a considerable gap between e-waste generated, e-waste officially collected, and e-waste that ends up in landfills. Finally there is very little official data regarding transboundary movement of e-waste, which occurs mostly from developed to developing countries.

The global quantity of e-waste generated in 2014 is estimated to comprise 1.0 Mt lamps, 3.0 Mt of Small IT, 6.3 Mt of screens and monitors, 7.0 Mt of temperature exchange equipment (cooling and freezing equipment), 11.8 Mt large equipment, and 12.8 Mt of small equipment. Nevertheless, the amount of e-waste is expected to grow to 49.8 Mt per year by 2018, with an annual growth rate of 4 to 5%. In 2014, the largest part of e-waste was generated in Asia: 16 Mt. This equals to an average of 3.7 kg per inhabitant. However, the highest per capita e-waste generation rates were recorded in Europe, with an average of 15.6 kg/inh. The whole region (including Russia) generated a total of 11.6 Mt. Whereas Oceania generated the lowest total amount of e-waste counting about 0.6 Mt total with a per inhabitant amount of 15.2 kg/inh. On the contrary, the lowest e-waste per inhabitant rate was registered in Africa, counting only 1.7 kg/inh, generating 1.9 Mt of e-waste altogether. Finally, the Americas comprehensively generated 11.7 Mt of e-waste 7.9 Mt of which in North America, 1.1 Mt in Central America, and up to 2.7 Mt in South America, with an average of 12.2 kg/inh (Baldé et al, 2014).

2.6 Urban Mining

Electric and Electronic Equipment contains various materials including hazardous, valuable and rare metals. Common hazardous materials found in e-waste are heavy metals such as mercury, lead, cadmium etc., and chemicals such as CFCs/chlorofluorocarbon or various flame retardants. However, in addition to hazardous materials, e-waste also contains many valuable materials such as iron, copper, aluminum and plastics, together with precious metals, such as gold, silver, platinum and palladium, which can be recycled. In fact, up to 60 elements from the periodic table can be found in complex electronics, and many of them are recoverable, though it is not always economically sustainable to do so today (UNEP, 2011).

From the resource perspective, e-waste is a potential "urban mine" that could provide a great amount of secondary resources good for re-manufacturing, refurbishing and recycling. For instance, the gold content from e-waste in, 2014 adds up roughly 300 tonnes, which represents about 11% of the global gold production from mines in 2013 (2770 tonnes) (USGS, 2014). Recovery of such valuable materials requires both high collection rates and recycling efficiency. In fact, in order to efficiently harvest resources through this "urban mine", the e-waste stream needs to be diverted to the formal take-back systems and avoid entering other channels such as waste bins or substandard recycling, because valuable materials are easily lost due to imperfect separation and treatment practices. In order to exploit the opportunities and simultaneously mitigate pollution, good policies are needed. Moreover, the creation of dedicated infrastructures would ensure that all collected e-waste is actually treated using state-of-the-art technologies, thus generating green employment opportunities.



(Table 8 *Recycling Rates of Metals A status Report*. UNEP, 2011)

As explained in chapter 1, there are several different methods for extracting valuable metals from an ore, in this case the ore being e-waste, the same methods can apply for metal extraction. Similarly to what happens for rock mining much depends on how these methods are used and what sort of safety procedures are put in place to ensure responsible emissions into the environment and protect human health. WEEE recycling in developing countries features an array of processes which are commonly used in the informal economy. Informal economies can constitute a considerable amount of the gross national product (GNP) of developing and transitional countries (Schneider and Enste, 2003). The activities of WEEE recycling in the informal sector are carried out by a range of legal, unregistered and publicly accepted businesses that give little concern to illegal and clandestinely executed processes which can cause extremely harmful consequences to the environment and to human health. These businesses collect, sort and manually separate electrical and electronic equipment. The processes involve applying crude methods to segregate substances and materials of interest from the electronic devices in which they are embedded. Numerous studies have described various WEEE recycling techniques. Some of the noticeably worst and most dangerous techniques include open burning of printed circuit boards (CBs) and cables (Brigden et al., 2005; Gullett et al.; Wong et al., 2007), burning of CBs for component separation or for solder recovery (Brigden et al., 2005; Wong et al., 2007c), toner sweeping, plastic chipping and melting, burning wires to recover copper, heating and acid leaching of CBs (Hicks et al., 2005; Leung et al., 2006), gold recovery from CBs with cyanide salt leaching or nitric acid and mercury amalgamation (Keller, 2006; Torre et al., 2006; Rochat et al., 2007), and manual dismantling of cathode ray tubes and open burning of plastics (Puckett et al., 2005; Jain and Sareen, 2006).

During these uncontrolled rudimentary practices, toxic substances are released. Three main groups of substances released during recycling can be identified: 1) original substances, which are constituents of electrical and electronic equipment; 2) auxiliary substances, used in recycling techniques and by-products, formed by the transformation of primary constituents. These substances are mainly leachates from dumping activities; particulate matter in the shape of coarse and fine particles deriving from dismantling and shredding; fly and bottom ashes from combustion; fumes from mercury amalgamate “cooking”, desoldering, and other heat treatments; 3) wastewater from dismantling and shredding facilities, effluents from cyanide leaching and other leaching activities or mercury amalgamation practices (Sépulveda et al. 2009).

The complexity of composition of electrical and electronic equipment thus imposes significant and new challenges for recycling. The complex connections between substances are often difficult to break up and separate due to limitations in separation physics as well as incompatible thermodynamics. It also means that often conflicting technical interests have to be solved: recovering certain substances can lead to the inevitable loss of others (Reuter and Verhoef, 2004; Hagelüken, 2006).

As a result, the WEEE Directive prime environmental strategies have become:

• Weight based recycling targets

• A single collection amount of 4 kg per inhabitant

• An origin-oriented categorization of products

• Selective treatment rules (by manual dismantling) for recyclers.

However, experiences show that WEEE policies should serve multiple and broader environmental goals. Significant developments in shredding and separation technologies suggest that dismantling as such, does not bring the desired toxic control as it depends much more on the destination of disassembled components and shredded fractions. In addition, there are relatively high costs involved. Technological progress in dedicated smelting and refining operations have resulted in improved yields for a wide range of metals, while simultaneously safely preventing emissions of hazardous substances (Hagelueken, 2006). Increasing focus is now placed on optimizing interfaces between dismantling, shredding, sorting and integrated metal smelting. In this context, the recovery of valuable materials (prevention of new material extraction also decreased emissions) and energy preservation have become much more important (Sépulveda et al, 2010).

Similarly to rock ore, bio-mining can also be used to extract valuable metals from e-waste. Recent developments have included using acidophiles to process electronic wastes, to extract metals from oxidized ores, and to selectively recover metals from process waters and waste streams (Johnson, 2014). In addition to copper and gold production, biomining is also used to produce cobalt, nickel, zinc, and uranium. Up to now, biomining has merely been used as a procedure in the processing of sulfide ores and uranium ore, but laboratory and pilot procedures already exist for the processing of silicate and oxide ores such as laterites, for leaching of processing residues or mine waste dumps also known as mine tailings, as well as for the extraction of metals from industrial residues and waste and will therefore be increasingly used in the recycling industry with similar advantages to those encountered in rock mining (Schippers et. al., 2014).

CHAPTER

3

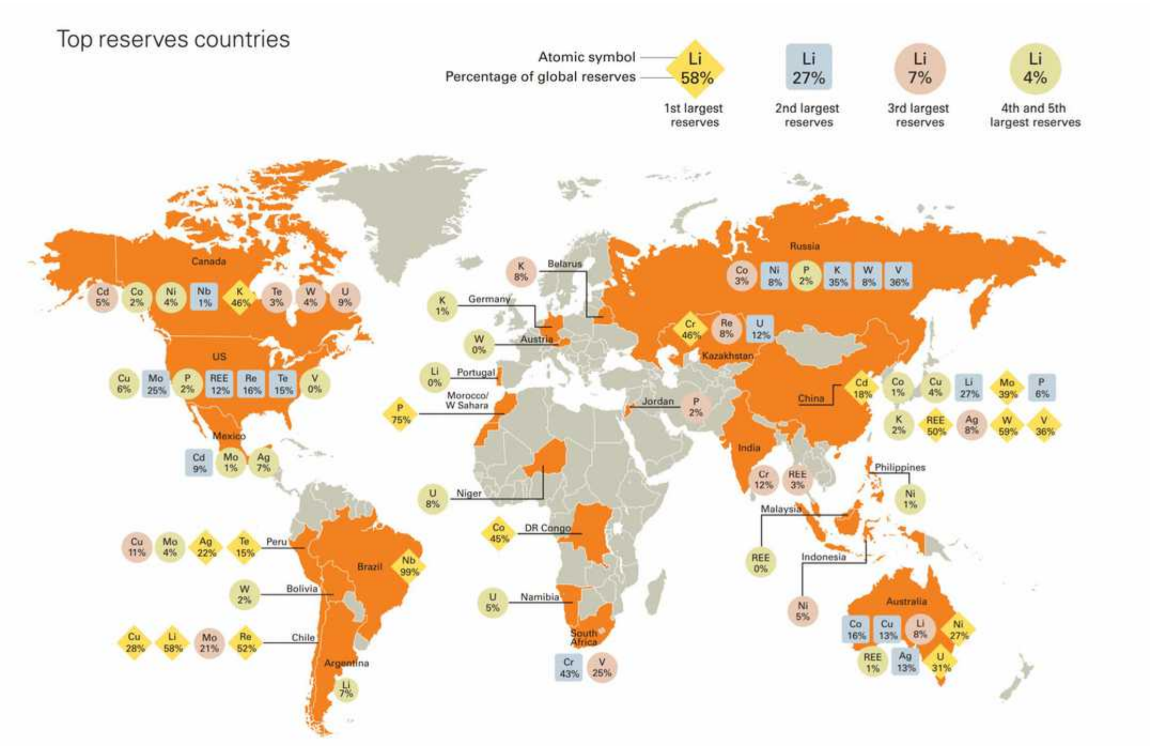
- Responsible use of Raw Materials -

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

(Brundtland Commission, UN 1987)

Introduction

As previously mentioned in chapter 2, great part of today's economy is already circular. Materials are extracted from the Earth and flow into manufactured goods, buildings and electronics. When these goods become obsolete and break down, the materials flow towards recycling hubs and a substantial part is re-cycled as feed stock into the economic system, other trash instead, end up in landfills. Along with formal circuits, there is an entire informal economy based on recycling. e-waste in particular is one of the fastest growing waste streams. Millions of tonnes of e-waste are in fact exported every year from developed countries to developing economies. Some of these international movements are registered and travel as “donations” to help bridge the digital divide. However, according to the country of origin there are are also great differences in the quality of the devices shipped. As a matter of fact, some of these shipments are filled with devices that are so obsolete, they are hardly useful for training programs, let it be for professional purposes. Other shipments are merely waste and travel under diverse definitions. In order to limit waste mismanagement and promote sound recycling, most countries worldwide have made efforts to pass regulations both on imports of raw materials (Dodd-Frank, 2010) as well as on waste management and exportation (Basel Convention, 1992).



(Image 7 Top reserve countries of Critical Raw Materials. EC, 2015)

3.1 Disclosing the Use of Conflict Minerals

In 2010, the United States Congress passed the Dodd-Frank Act, which requires companies to disclose their use of conflict minerals if those minerals are “necessary to the functionality or production of a product” manufactured by those companies. Under the Act, such minerals include tantalum, tin, gold and tungsten. This Act was passed by the U.S. Government because of concerns that the exploitation and trade of (conflict) minerals by armed groups is helping to finance conflict in the DRC region and is contributing to an emerging humanitarian crisis. (Dodd-Frank, Section 1502). The Act lists the following covered countries Democratic Republic of the Congo (DRC), Central Africa Republic, South Sudan, Zambia, Angola, Tanzania, Burundi, Rwanda and Ouganda. According to the SEC, the covered Countries account for 15% to 20% of the world's supply of tantalum and smaller percentages of the other three minerals. The final rule applies to all companies that use minerals including tantalum, tin, gold or tungsten when these minerals are "necessary to the functionality or production" of a product manufactured or contracted to be manufactured by the company.

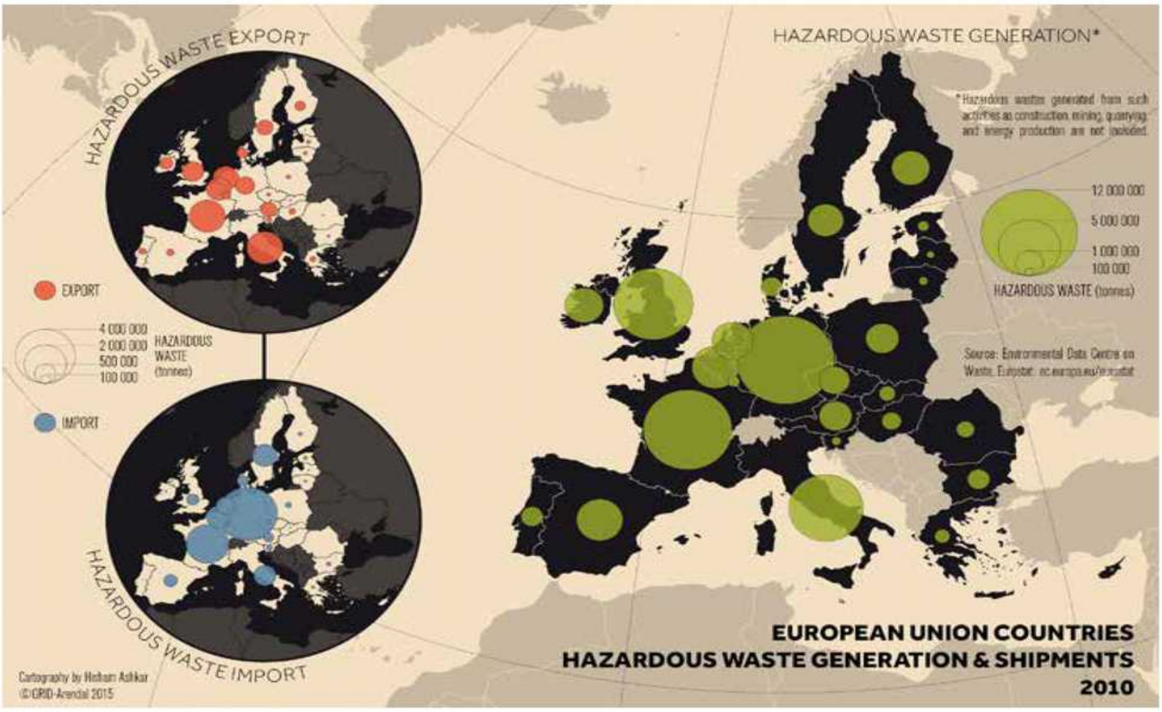
The rule, in fact, also requires a company to provide disclosure in case of contracting manufacture. A company is considered to be "contracting to manufacture" a product if it has some actual influence over the manufacturing of such product. This determination is based on facts and circumstances, taking into account the degree of influence a company exercises over the product's manufacturing. However, a company is not deemed to have influence over the manufacturing if it merely affixes its brand, marks, logo, or label to a generic product manufactured by a third party, services, maintains, or repairs a product manufactured by a third party. Such requirements apply equally to United States domestic and foreign issuers. In addition, a company that uses any of the designated minerals is required to conduct a reasonable 'country of origin' inquiry that must be performed in good faith and be reasonably designed to determine whether any of its minerals originated in the covered countries or are from scrap or recycled sources. According to the results of this inquiry the company is required to file a report and to make such information public on the company website under one of these three definitions: "DRC conflict free," not "DRC conflict free" and "DRC indeterminable." In case the inquiry results are indeterminable or the minerals are proven to come from the covered countries, the company must exercise due diligence measures and conform to a nationally or internationally recognized due diligence framework, such as the due diligence guidance approved by the Organisation for Economic Co-operation and

Development (OECD, 2013). In addition, the company will have to declare the steps it has taken or will take to mitigate the risk that its conflict minerals benefit armed groups, including any steps to improve due diligence.

Finally, there are special rules governing the due diligence and Conflict Minerals Report for minerals from recycled or scrap sources. If a company's conflict minerals are derived from recycled or scrap sources rather than from mined sources, the company's products containing such minerals are considered "DRC conflict free." However, if a company cannot reasonably conclude after its inquiry that its gold is from recycled or scrap sources, then it is required to undertake due diligence and get an audit of its Conflict Minerals Report. Currently, gold is the only conflict mineral with a nationally or internationally recognized due diligence framework for determining whether it is recycled or scrap. For the other three minerals, if a company cannot reasonably conclude after its inquiry that its minerals are from recycled or scrap sources the company is required to describe the due diligence measures it exercised in determining that its conflict minerals are from recycled or scrap sources and do not have to seek private auditing (SEC, 2016). Most of the dispositions of the Dodd-Frank Wall Street Consumer Protection Act, including those regarding Conflict Minerals, have been received and interpreted by the European Market Infrastructure Regulation (EMIR), which entered into effect in 2014.

3.2 Basel Convention

Mining and the origin of materials is not the only concern. As a matter of fact, also the waste produced by human activities is a major concern in the political debate of the last three decades. In particular, the Basel convention of 1992 was signed by all European countries and by most of the countries around the world. This document regulates the export of toxic and hazardous substances from a rich country to a developing economy, however, there are still many gray spots both in the legislation and in the application of such regulations. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in 1989 and came into force in 1992. It is the most comprehensive global environmental agreement on hazardous wastes and other wastes. With 181 Parties (as at 18 July 2014), it has nearly universal membership. The Convention aims to protect human health and the environment against the adverse effects resulting from the generation, transboundary movements and mismanagement of hazardous wastes and other wastes. The Basel Convention thus regulates transboundary movements of hazardous wastes and other wastes and obliges its parties to ensure that such wastes are managed and disposed of in an environmentally sound manner. The Convention covers toxic, poisonous, explosive, corrosive, flammable, eco-toxic and infectious wastes. Parties also have an obligation to minimize the quantities that are transported, to treat and dispose of wastes as close as possible to their place of generation and to prevent or minimize the generation of wastes at source. 14 Basel Convention Regional and Coordinating Centres have been established under the Basel Convention. The centres are located in Argentina, China, Egypt, El Salvador, Indonesia, Islamic Republic of Iran, Nigeria, Russian Federation, Senegal, Slovak Republic, South Pacific Regional Environment Programme (Samoa), South Africa, Trinidad and Tobago, and Uruguay.



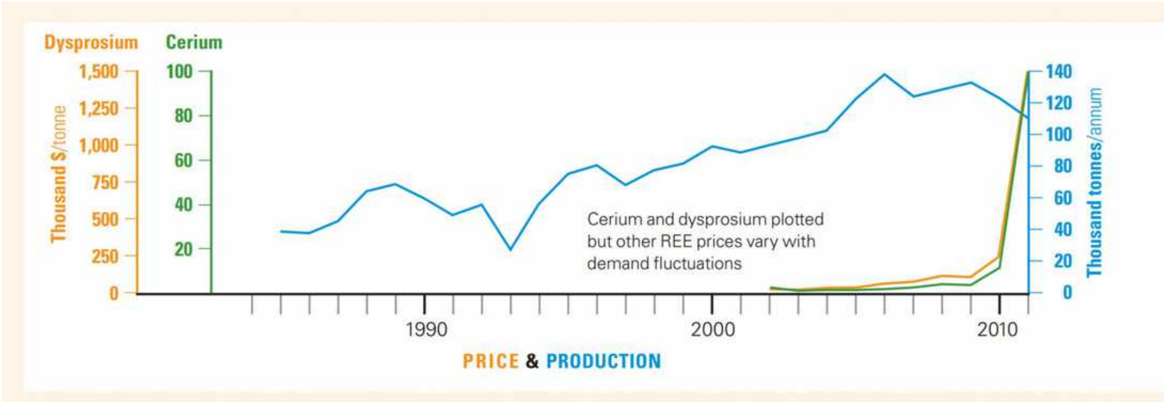
(Image 8 *European Countries Hazardous Waste Generation & Shipments 2010*, from *Waste Crimes – Waste Risks* UNEP, 2015, p.56)

They deliver training and technology transfer regarding management of hazardous wastes and other wastes and the minimization of their generation, so as to assist and support Parties in their implementation of the Convention (UNEP, Basel Convention, 2014).

3.3 Critical raw materials and supply risk in Europe

The geology of the Earth is extremely heterogeneous and thus mineral deposits are unequally distributed across borders. The mineral wealth of a country and its geological availability, is therefore predetermined by nature. However, the actual use of this wealth depends on its attractiveness for economic activity within a political and social framework. Given that only a small percent of the Earth's surface and subsurface have been explored in detail, the potential for discovering new mineral deposits is vast and the geological availability is still indefinite. In such a context, the main issue concerns exploration and technological developments that will allow for a sustainable exploitation of resources, rather than geological scarcity (EC, 2010).

Regarding critical raw materials, their high supply risk is mainly due to the fact that a high share of the worldwide production comes from China (antimony, fluorspar, gallium, germanium, graphite, indium, magnesium, rare earths, tungsten), Russia (PGM), the Democratic Republic of Congo (cobalt, tantalum) and Brazil (niobium and tantalum). This production concentration, in many cases, is supported by the low substitutability and low recycling rates of such materials. Therefore, a slight change in the variables may result in one of these materials being reclassified as 'critical'. Several of these materials are notably industrial minerals. Possible supply risks may occur within a longer time horizon, affecting production from quarries or mines of such materials within the EU (EC, 2014). Technological advancement is certainly one of the most powerful forces influencing the economic importance of raw materials in the future. In many cases, rapid diffusion of new technologies can drastically increase the demand for certain raw materials as has happened for Rare Earth Elements in the last decade as stated by the 2014 British Petroleum Report on Materials Critical to the Energy Industry (Zepf et al, 2014).



(Table 9 *Price and Production Diagram of Rare Earth Elements*. Zepf et al., 2014 p.55)

Based on a study commissioned by the German Federal Ministry of Economics and Technology, the demand driven by emerging technologies is expected to evolve very rapidly by 2030. Raw materials are essential for the efficient functioning of Europe's economy. However, whereas the importance of oil and gas has often been highlighted, the essential role of non-energy materials such as minerals and metals has not received equal attention. Yet, industrial minerals are indispensable for a wide range of industries. Most people are usually not aware that feldspar is used in the production of televisions and computer screens, car headlamps, and soda bottles; silica is used in products such as tableware, ornaments, wall and floor tiles; while talc can be used to improve the performance of biological wastewater treatment plants. Metals are also essential to modern industrial activity as well as to the infrastructure and products used in daily-life. For instance, copper and aluminum are used in cables that transport electrical power over great distances to the most remote locations, and zinc protects the steel infrastructure that supports them under all weather conditions. Moreover, high tech metals are indispensable ingredients for the development of technologically sophisticated products. Modern cars, flat-screen televisions, mobile phones and countless other products rely on a range of materials, such as antimony, cobalt, lithium, tantalum, tungsten and molybdenum. The same group of high-tech metals are also fundamental to new environmentally friendly products, with electric cars requiring lithium and neodymium, car catalysts use platinum, solar panels require indium, gallium, selenium and tellurium, energy efficient high-speed trains necessitate cobalt and samarium, and new fuel-efficient aircraft cannot work without rhenium alloys. All these minerals and metals are present everywhere in society today (EC, 2014).

Europe is highly dependent on imports for many raw materials. Such materials are often affected by the growing demands of emerging economies and by an increasing number of national policy measures that disrupt the normal operation of global markets. Moreover, the production of many materials is often concentrated in a small number of countries. For example, more than 90% of rare earths and antimony, and more than 75% of germanium and tungsten are produced in China, while almost 90% of niobium comes from Brazil and 77% of platinum is extracted in South-Africa. In addition, high tech metals are often byproducts from mining and processing of major industrial metals, such as copper, zinc and aluminium, which means that their availability is largely determined by the availability of the main product. Besides, due to the fact that it can take 9 to 25 years to develop a large copper project, mining features low supply elasticity. Thus, mining cannot quickly adapt in meeting structural changes in the demand pattern. This increases the risk of crises, such as the rush for tantalum in 2000 due to the boom of mobile phones.

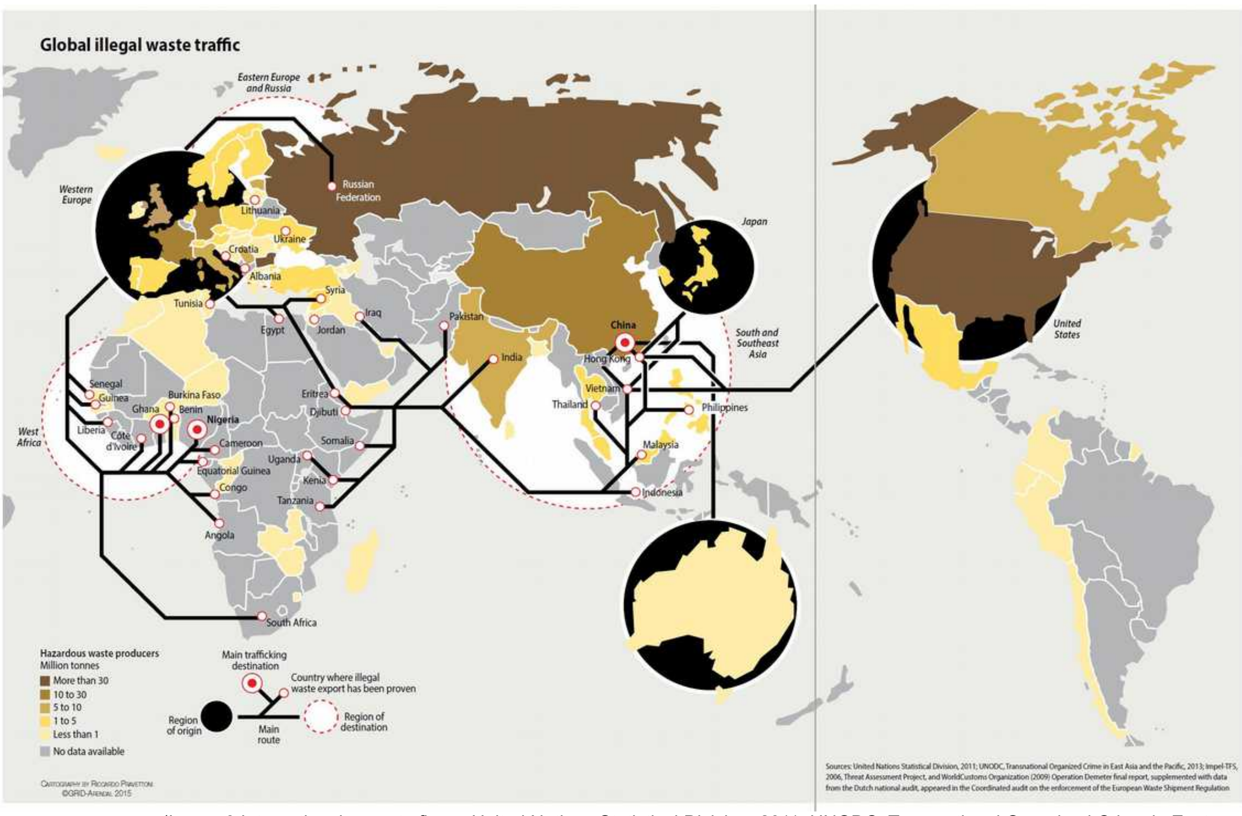
While the EU still has valuable deposits and much under-explored and unexplored geological potential, their exploration and extraction faces increased competition for different land uses and is required to take place in a highly regulated environment. Member States are increasingly aware of these challenges. At the same time, a significant opportunity exists for securing material supplies by improving material efficiency and recycling. In order to address these complex and interrelated challenges, the European Commission has launched an integrated strategy in November 2008: the EU Raw Materials Initiative. This initiative encompasses measures to secure sustainable access from outside Europe, improving framework conditions for extracting minerals within Europe, and promoting the recycling and resource efficiency of such materials.

3.4 Waste crimes and international flows

Use of mineral resources to produce consumer goods has not only favored conflict in certain areas of the world (chapter 3.1) and is currently creating extremely interdependent economies. The waste produced by the global consumerist society is also posing major threats to ecosystems, the environment as well as to human health. As a matter of fact, both the industrial production of disposable goods as well as the final use-and-discard habits of western culture have produced and are currently producing increasing amounts of complex materials which flow into likewise complicated waste-streams. Some of these also contain toxic elements as described in chapter 2. For decades and still nowadays, a lot of the toxic waste produced in rich countries is exported, both legally and illegally towards developing economies, where legislation is often lax (Kangaspunta et al., 2009) and governments are more prompt to act as Olson's “roving bandit” (Olson, 2000). In order to export toxic waste, there must be at least the collaboration between three actors all of which profiting from the business. These are the “polluter” or company wishing to get rid of some undesired and undesirable substances, a “transporter” consenting to transport a risk load, use shadow flags and capable of unsuspectingly load and unload the vehicles. Finally, there is a “receiver” willing to provide a dump site in exchange for some economic benefit. Often, illicit markets cooperate in “complex and often unpredictable ways” (Williams et al, 2002) which make it very hard for authorities to identify and pursue eco-crimes in general. (Kangaspunta et al, 2009)

On August 25, 2015, the Countering WEEE Illegal Trade project (CWIT) published the results of a two year investigation. This study estimates that e-waste mismanagement “results in a serious loss of materials and resources for compliant waste processors in Europe. This annual estimated loss is valued between EUR 800 million and € 1.7 billion (USD 877 million to 1.86 billion)” (Interpol, 2015). The increase in unlawful treatment of e-waste is tightly bound to the precious metal content of this particular type of waste. Therefore the rise of market value of precious metals directly influences the profitability of e-waste treatment and illegal trafficking. “About 41.8 million metric tonnes of e-waste was generated in 2014 and a substantial part of it was handled informally, including illegally. This could amount to a business flow of as much as $18.8 billion annually. Without sustainable management, monitoring and good governance of e-waste, illegal activities may only increase, undermining attempts to protect health and the environment, as well as to generate legitimate employment" (UNEP, 2015).

In addition to precious metals, e-waste also contains other materials which are harmful to the environment and to human, plant and animal health such as mercury, lead, arsenic and many others. These elements are particularly hazardous when released into the environment by indiscriminate dumping into soil and water or worse yet if burned into the open air (Widmer et al., 2005). Therefore, artisanal recovery of metals as well as dumping practices result not only in material loss of valuable elements, but also pose serious threats to the environment and ecosystems as well as to human health (Ludgren, 2012).



(Image 9 International e-waste flows. United Nations Statistical Division, 2011; UNODC, Transnational Organized Crime in East Asia and the Pacific, 2003; Threat Assessment Project and World Customs Organization, 2009 Operation Demeter Final Report. From Waste Crimes-Waste Risks, UNEP, 2015, p. 54-55)

Concerning shipments, the ports of northwest Europe (for example, Tilbury and Felixstowe in England and Antwerp in Belgium) and of the Mediterranean are the ones mainly used to transport Europe's e-waste, which is shipped as second-hand electronics, and end-of-life vehicles to West Africa and Asia. E-waste is most often shipped in containers to ports in Nigeria (Lagos, Tincan Island), Ghana (Tema), and Benin (Cotonou). European environmental authorities are investigating the potential for e-waste shipments to Africa via roll-on roll-off ferries (UNEP, Waste Crime – Waste Risk, 2015). A recent trend shows how the EU is exporting an increasing amount of waste materials to other countries, mainly in Asia. Especially for valuable metals but also for plastics and this increase is significant. From 1999 to 2011 the export of iron and steel waste has increased by 160%, of copper, aluminum, by 210% for Nickel and by 140% for precious metals. For plastics the increase is as high as 600% (Sand, Rosenkranz, 2014).

Over the past two decades, policymakers, producers and recyclers have created specialized systems to collect e-waste from the final owners and process it in safe treatment facilities. However, collection and state-of-the-art treatment of e-waste is yet to be perfected, and most nations worldwide are still missing proper e-waste management systems. Furthermore, a noticeable part of the world's e-waste is shipped great distances from developed to developing countries, where they are treated in sub-standard processes using inefficient techniques in order to extract the valuable components. These "backyard" techniques pose major health hazards to the operators lacking proper personal protection equipment (PPE) and further disposal of toxic and acid residues also poses major threats to the environment and wildlife. Global trading of electronics and substandard recycling in developing countries has led to environmental catastrophes in places like Guiyu, China and Agbogbloshie, Ghana, to name two examples (UNEP, 2015).

3.5 Recycling Europe

The new European Innovation Partnership (EIP) on Raw materials, gathers many different players, including Member State authorities, industry, research organizations and civil society to develop a plan composed of a comprehensive set of research and innovation actions under three pillars: technology, non-technology and international cooperation. Through this Strategic Implementation

Plan, the European Union is thus addressing two main challenges, which are crucial for a strong EU industrial base as an essential building block of the EU's growth and competitiveness:

- High dependence of the EU on imports
- Security of supply of raw materials within the EU

Sectors depending on access to raw materials, such construction, chemicals, automotive, aerospace, machinery, equipment, renewable energy devices, have a combined added value grater than EUR 1,000 billion and provide employment for some 30 million people (EC, 2015).

Due to the high consumption of metal containing products, Europe could be considered having a large potential in the recycling of secondary raw materials. In fact European companies like Boliden (Sweden), Umicore (Belgium) and Aurubis (Germany) are among the world leader recycling companies when it comes to non-ferrous metals (Sundqvist, 2012). Therefore, at least part of EU's need for raw materials can be covered by these types of recycled resources. Many EU policies addressing this issue, put a high emphasis on recycling and substitution (Strategic Implementation Plan, Part I, 2013).

CHAPTER

4

- Moving Towards Circular Economy -

“Thus, totality is nothing else but plurality contemplated as unity.”

(Kant, 1781)

Introduction

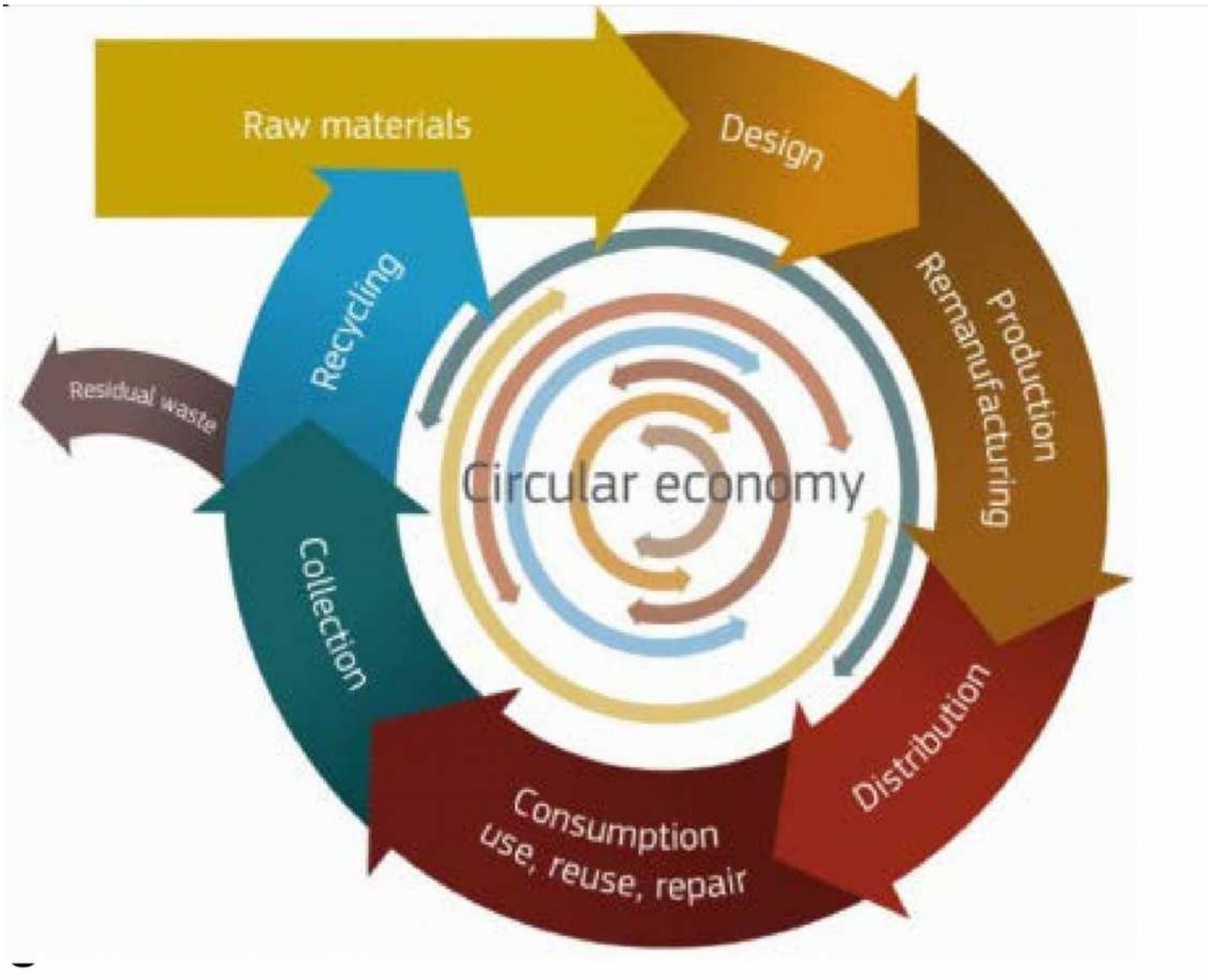
This chapter focuses on practical actions necessary to develop new holistic approaches to the increasing challenges posed by the linear system of technological products in particular. The main purpose of this section is to question how design can improve the end-of-life cycle of electronic commodities. Improved design and repair-ability of electronic devices have the potential of dramatically improving disassembly operations, which can thus be safely conducted at a micro level. Well managed micro processes are flexible and can help addressing materials and potentially hazardous elements into formal and safe recycling systems. Spreading the labor throughout the territory is a potential driver of change with the ability to generate new jobs and professional profiles in Just-On-Time (J.O.T.) waste management and collection systems. This would involve society and students in developing and improving flexible and efficient take back systems in collaboration with National and International institutions both locally and worldwide.

4.1 Use of materials

Growing population and the increase of wealth brought by the staggering development of the last decades, in Asia in particular, together with the ongoing development of new technologies and upgrading product performance have been driving the demand for technology metals.

"Technology Metals" is a descriptive expression comprising most precious and special metals. These are crucial for technical functionality based on their unique physical and chemical properties such as conductivity, melting point, hardness, catalytic, optical or magnetic properties. Technology metals are often used in low concentrations and in complex substance mixes which makes them very difficult to separate at the end-of-life of the object they are built into. Extracting technology metals requires great investments and generates a heavy carbon footprint. State-of-the-art recycling, on the other hand, is far less energy intensive than mining and yields far more technology metals per metric ton processed, thus improving access to raw materials. Production of Electric and Electronic Equipment (EEE) requires over 40% of world mine production of Copper, Tin, Antimony, Indium, Rhutenium and Rare Earth Elements (REE). Mobile Phones and Computers, for instance, account for 4% of world mine production of Gold and Silver and for 20% of total Palladium and Cobalt consumption. Over 60% of Platinum Group Metals (PGM) extracted are used in the car industry as autocatalysts. As the automotive industry develops increasingly technological models, the demand for light metals and technology metals used for electronics, has and will grow accordingly. In the last 30 years we have extracted over 80% of Rare Earth Elements. Platinum Group Metals, Gallium, Indium, etc.... than has ever been mined before in history altogether. Clean energy technologies and other high tech applications will further accelerate the demand for technology metals such as Precious Metals, semiconductors, Reare Earth Elements, Refractory Metals, etc... Without access to these metals there cannot be any sustainable development (Meskers, 2014).

The EU is, from a global perspective, relatively dependent on imports. Imported goods, in fact, hold a substantial share in the European economy. The highest impact of longer product lifetimes will be on consumer demand for final products. Electric and electronic equipment, textiles, transport equipment and furniture rank high on consumption from imports. This means that a longer lifetime of these products is most likely to influence the trade balance because fewer imports will be required to maintain the current level of B2B and B2C stock in the European market. Increasing standards can actually increase a manufacturer's profits (Lacourbe, 2015).



(Image 10 *Circular Economy Diagram*. www.acceleratio.eu, 2016)

4.2 Sustainable secondary raw material management

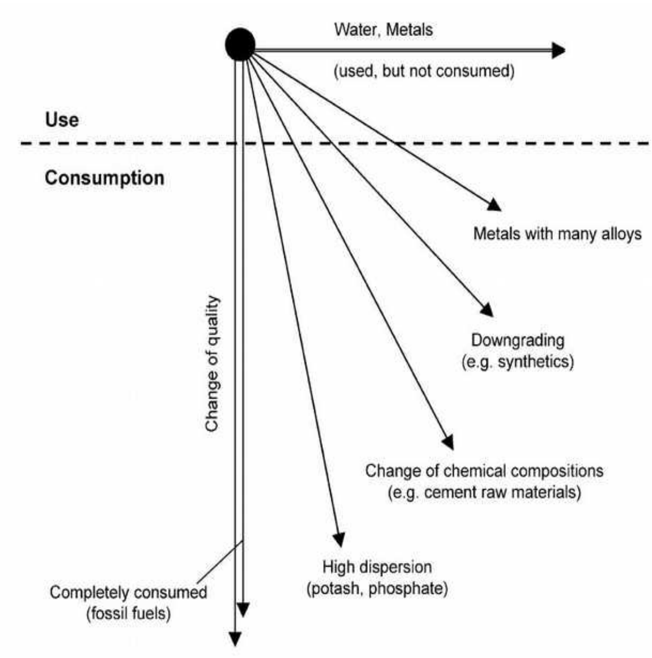
In order to establish safe and reliable circular economic models requires the identification the potentials of recycling and substitution of raw materials and how much is technically, economically, environmentally optimal. This requires a solid framework of economic instruments and incentives able to push the boundaries of technological innovation within the physical limits of recycling and substitution.

Improving collection and recycling systems and fostering R&D for sorting technology is certainly one of the actions necessary to move towards efficient and responsible material use, but it is not enough. Collection, in fact mostly depends on consumers' behaviors. Therefore there must also be adequate widespread consumer awareness to promote return and proper management of relevant products such as WEEE. Yet, much can be done along the supply chain, starting with the support to green procurement in both public and private sectors, including procurement of long-life products, repaired or second hand products and products made from recycled materials, and encouraging use of certified refurbishing and recycling facilities for end-of-life treatment of procured products.

A supportive framework of regulations supporting Extended Producer Responsibility must ensures that high quality recycling operations are able to charge sufficient prices to enable them to operate in an economically viable way. While integrating generic recycle-ability and durability criteria into eco-design requirements starting from designing products to make them easy to repair and reuse, where possible, or making them safe and easy to dismantle, deconstruct and recycle. Other effective action plans include fostering free and fair trade of primary and secondary materials and facilitating shipments of waste to EU based recycling facilities which can demonstrated to operate under high treatment standards based on a certification system. Further steps for boosting collaborative initiatives to facilitate circular economy policies shall allow the creation of networks to exchange information and promote industrial symbiosis. Finally, raising widespread awareness all along the value chain plays a fundamental role both in shifting demand towards better designed products using responsibly supplied raw materials and will eventually improve collection by pre-sorting collection streams (RREUSE, 2015).

4.3 Limits of recycling

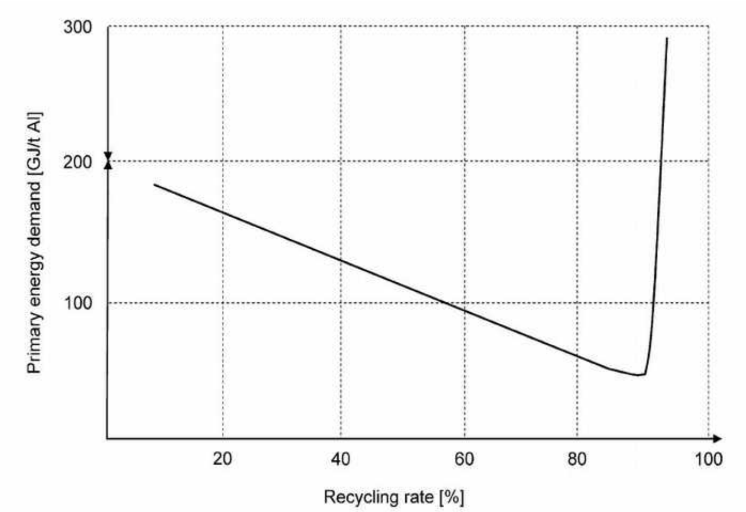
Up until here we have investigated the origins of raw materials, from mining to the opportunities offered by urban mining. Recycling can certainly respond to part of the needs for materials of humans, however there are some limitations and drawbacks. Recycling in fact cannot respond alone to the increasing needs of production. According to the nature of the different materials used by the industry, some may not even be recyclable to begin with, such as fossil fuels which are burned up during the process. Fossil fuels in fact are non recyclable nor reproducible resourced by definition. Other materials are subject to chemical transformation and their chemical composition changes when they are used making an inverse re-generation process extremely expensive and sometimes impossible. Materials such as concrete and thermo-setting plastics are some examples of materials which are very hard to recycle and often must be down-cycled since they can only serve as rubble and filling materials in construction works.



(Table 10 Changes of quality during recycling of materials from the geosphere and Technosphere from Wellmer and Kosinowski, 2005; Richards, 2009, p. 105)

Other materials such as thermo-plastic synthetics can be recycled a certain number of times, but the molecules and chemical-physical structure will eventually downgrade at each “re-cycle” and are therefore doomed to become weaker and weaker each time, gradually losing the material properties which make them useful. Finally, other elements such as pure metals and water can be used and reused virtually infinite times and at each cycle they are completely regenerated and do not present any significant difference from the mined virgin material. However, as seen in Chapter 3, complex alloys and material mixes make it very difficult and expensive to recover certain elements and often recovering one part prevents the recovery of others due to technological, chemical, physical and economical constraints. Hierarchy of resources in Sustainable Development Table 10 (Wellmer, 2005)

Moreover, also considering fully separated pure metals, there are energetic trade-offs which define the optimal recycling rate. For example the optimal recycling rate for aluminium used in light-weight packaging material is 90%. Any higher or lower recycled material imput results in higher energy demand.



(Table 11 The optimal recycling rate for aluminium used in light weight packaging is 90%. Any higher or lower rate results in higher energy demand. Redrawn and modified after Rombach, 2006; Richards, 2009, p.107)

Observing the diagram it is interesting to note how the curve smoothly declines as the recycling rate increases up to 90% and abruptly verticalized as the recycling rate passes 90% making higher recycling rates extremely expensive and energy intensive even higher than using solely virgin material (Richards, 2009).

Taking into consideration these physical constraints it appears clear that 100% recycling and therefore a completely circular economy cannot exist. There will indeed always be the need for virgin raw material input also in the best recycling processes and therefore, recurring to mining, will always be crucial to supporting human societies now and in the future.

4.4 Eco-design

Despite the physical constraints deriving from the very nature of the materials we use, there is still a wide gap between current consumption trends, waste disposal and state of the art recycling. There is hence room for improving the life span of everyday objects as well as collection and recycling systems. Design in particular, plays a fundamental role in changing critical aspects of the end-of-life cycle already in the production phase. Skilled design can potentially break the schemes of consumerism by tackling critical issues such as repair-ability, disassemble-ability, interchange-ability, upgrade-ability, compatibility and recycle-ability of products, improving production efficiency and promoting non-exclusive, creative and sharing approaches.

Since material requirements and related social-ecological impacts are determined to a great extent during the design phase, also the training of designers must address these critical issues, focusing on providing skills for better product design. In particular, skills needed for environmentally friendly products include cross-disciplinary approaches bringing together engineering and design, thus enabling the development of attractive, cost efficient, and resource efficient products. In addition, product design constraints should include guidelines to improve environmental product performance throughout the whole life cycle. Thus, repair-ability, longevity, recycling and waste minimization must be taken into account already in the product development and advertising phase. Increased consumer awareness will eventually encourage the use and demand of products efficiently and correctly designed. Finally, there is space for specialization in building documentation for the production and availability of spare parts.

Product performance and post-sale support also represent a fundamental characteristic that must be taken into consideration in the designing phase. Making repair attractive to young people will increasingly motivate consumer behavioral change from “produce-consume-discard” attitudes to new products designed to be repaired, upgraded, disassembled and recycled. Finally, providing a supportive framework and implementing incentives for eco-design on a macro-level will allow the creation of standards for the production of compatible products and spare parts, thus orienting public procurement to demand eco-designed products from the consumers side. Whereas, providing a supportive framework and incentives for eco-design at micro-level will foster top-level management awareness, thus promoting the benefits of eco-design and consequently promoting eco-design of products. There is a wide array of government incentives that can be put in place ranging from scholarships for businesses to fostering collaborative platforms for funding and pooling ideas. Moreover, the creation of specific product or service groups with different representatives along the value chain will eventually allow pilot testing and implementation of new business models, hence providing consumers with relevant, targeted, sufficient and accessible information to enable increasingly informed markets and consumer choices (EEB, 2015).

4.5 New business models

"The notion of new business models underpinned by new products, functions, services and practices has received much attention over the last five years (Boons et al. 2013; Schaltegger et al. 2015). The advent of new design, manufacturing and information technologies applied to the way companies run their manufacturing operations offers great potential to the benefits of longer product lifetimes. Currently companies are experimenting with new ways of manufacturing, making the series of production of "one" fully customized product a reality. This offers a new dimension for consumption patterns moving from depersonalized products and services to full bespoke customer intimacy with new products that imply far more loyalty and attachment for the longer term towards specific products that follow the design, expected lifespan and quality requested by clients. This new product scenario opens a completely different way of consuming and of keeping consumer goods for a longer time […] the option of supporting new business models requires new policy approaches, which have, at the moment, not been developed in sufficient detail. The availability of instruments like Horizon 2020 is currently enabling experimentation with new pilot lines for smart manufacturing as well as new business models for the circular economy. Major challenges in this new type of business model are to create one-of-a-kind, bespoke, products that comply with product standards, certification and safety" (European Parliament, 2016, p. 75).

CHAPTER

5

- Future Perspectives -

Case studies

"Per aspera sic itur ad astra"

(Cicero, 44 BC)

Introduction

This chapter includes a selection of case studies on future perspectives of resource availability, reporting some of the most outstanding projects which are currently being implemented. From landfill mining to deep rock mining all the way to deep sea mining, the quest for materials is pushing man to prospect the depths of space. Finally, this ever growing race for materials is generating ever more complex waste itself, such as Space Waste and Orbital Debris, a problem to come to which the last case study is dedicated.

5.1 Landfill Mining

In a circular economy material loops are closed by recycling of pre-consumer manufacturing scrap and residues. This can be carried out through several operations such as urban mining of end-of-life products and landfill mining of historic and future urban waste streams. However, landfill mining has not yet been performed with a focus on resource recovery. The European Landifll Mining Consortium (EURELCO) was established in 2014 to introduce the concept of Enhanced Landfill Mining, defined as the safe conditioning, excavation and integrated valorization of landfilled waste streams as both materials and energy, using innovative transformation technologies and respecting the most stringent social and ecological criteria. The feasibility of Enhanced Land Fill Mining (ELFM) is studied by synthesizing the research on the Closing the Circle project, which was the first ELFM project excavating an 18 million metric ton landfill in Houthalen-Helchteren in the East of Belgium. It is argued that Environmental Impact Assessments of ELFM projects should be wide in scope and time. Embedded in a broad resource management perspective, the worldwide potential of ELFM is highlighted, in terms of climate gains, materials and energy utilization, job creation and land reclamation. However, for ELFM to reach its full potential, strategic policy decisions and tailored support systems, including combined incentives for material recycling, energy utilization and nature restoration, are required.

As the world is facing unprecedented environmental challenges (Rockström et al., 2009) and resource shortages (European Commission, 2010), the transition towards resource efficient, low-carbon circular economies is a necessity. In drawing a road map for a Resource Efficient Europe, the European Commission (2011) envisions that by 2020 waste will be managed as a resource. Recycling and reuse of waste have, in fact, become economically attractive options and final energy recovery is limited to non recyclable materials. Landfilling, as we know it, shall be eliminated. As described by Jones et al. (2011), in a circular economy material loops must be closed by direct recycling of pre-consumer manufacturing scrap and residues as well as fostering post-consumer repair, reuse and recycling.

In any cases the need for energy and carbon intensive mining of primary materials can be reduced (Ayres, 1997). Among other good practices, the landfill mining approach aims at transforming landfills from a major cost to society due to the their contribution to global warming (Sormunen et al., 2008), the risk of groundwater pollution implied in landfilling practices (Flyhammar, 1997), and the occupation of valuable land, into a resource recovery opportunity.

Estimates indicate that throughout the EU there are between 150,000 and 500,000 historic and still active landfills (Hogland et al., 2011; Vossen, 2005), which can deliver a significant stream of secondary materials and energy. Nevertheless, integrated resource recovery from landfills is a topic which has received surprisingly little attention in literature (Krook et al., 2012). There is therefore a deep need in focusing on a landfill-for-resources strategy. (Jones, 2012). By 2020 Enhanced Landfill Mining is expected to be implemented EU-wide as a key component of a resource efficient, circular and low-carbon economy. EU’s landfills will provide for a substantial part of the EU’s material, energy and land needs. ELFM has paved the way for breakthrough exploration, separation, transformation and up-cycling technologies that are also used for recycling and urban mining of newly produced waste and residues.

5.2 Deep Land Mining

Due to the dependency of Europe on imports for the satisfaction of the Union's needs of raw materials, one of the largest projects funded by Seventh Framework Programme has been the I²Mine Deep Mining project. The project involves 27 partners from 10 European countries. The budget is of a remarkable 25,4 M€ of which 16 M€ are from EU contribution. The Project involves 2.300 person-months for a total of 191,7 person-years. The project's vision is to combine a Futuristic Intelligent Deep Mine with very low environmental and social Impacts into a sort of Invisible Mine.

General objectives aim at reducing impacts of deep mining in order to gain social license to operate and Exploit the known and predicted European mineral deposits, thus reducing import dependency for mineral raw materials. Achieving such ambitious goals requires the development of innovative methods, technologies, machines and equipment for mining in greater depths which will call for trained engineers and further investments in mining technology. Autonomous, highly selective mineral extraction processes and machinery will be highly technological devices with new sensor technologies. Also prospecting and mine planning and engineering require completely different mine layouts and innovative concepts for mass flow management and transportation. Further developments required for the project are Improved rock mechanics, ground control, novel mining and underground processing methods.

The final goal is to develop new advanced, intelligent and safe underground mining concepts and technologies and utilize deep strategic mineral resources for a competitive EU industry. The project will also considerably relieve environmental damages like subsidence, urban congestion, noise and pollution by transferring structures below ground level, and making them invisible. ultimately the underground related industries shall become highly technological and competitive on global markets.

The development of innovative machinery for deep underground mining plays a key role in providing machine guidance for precise positioning and cutting trajectory along with integrated process optimization on autonomous mining machinery as well as mineral sorters for underground pre-processing of extracted material. Finally, the development of health and safety criteria and guidelines for new mining concepts along with studies and analyses of new production technologies will be made regarding job content, work organization, physical risks etc. Personnel will be trained in a road-header cutting simulator, thus developing and establishing the innovative concept of “virtual training.” Still, there are numerous and comprehensive challenges including the high level of International and interdisciplinary cooperation required, both in the technical and socio-economical field. Tackling the challenges of resource availability calls for a new and modern vision based on socio-technical approach along the whole value chain. I²Mine marks the start of such cooperation, paving the way to sustainable deep mining in the future (Hejny, 2014).

5.3 Deep Sea Mining

The quantity of minerals occupying the ocean floor is potentially large. Seabed mining is concerned with the retrieval of these minerals with the objective of ensuring security of supply and filling a gap in the market where recycling is neither possible nor adequate, or the burden on terrestrial mines is too great. Numerous organisations within the EU are presently engaged in seabed mining activities, both as technology providers and as mine operators. The sector, though small, has been identified as having the potential to generate sustainable growth and jobs for future generations. However, our lack of knowledge of the deep-sea environment necessitates a careful approach. In particular, research is now focusing on robotics, video-surveillance and submersible technology in particular, while modern machinery allows operations that were not feasible ten years ago.

As we grow increasingly aware that land and freshwater are finite resources, further clearing of forests or draining of wetland will deprive future generations of the benefits these provide, whereas meeting environmental targets can also be a source of innovation and growth. Finally, the need to reduce greenhouse gas emissions has not only driven offshore renewable energy installations, but has opened up an opportunity for blue growth. Growth in the blue economy offers new and innovative ways to help steer the EU out of its current economic crisis. It represents the maritime dimension of the Europe 2020 strategy. It can contribute to the EU's international competitiveness, resource efficiency, job creation and new sources of growth, whilst safeguarding biodiversity and protecting the marine environment.

Between 2000 and 2010 there has been an annual increase of about 15% in the price of many non-energy raw materials (WTO, 2011), mainly as a result of consumer demand in emerging economies. There is a risk of supply shortage for several of these, including those identified as critical to Europe's economy (LME, 2010). Advances in technology as well as concerns over security of supply have encouraged mining companies to consider what the sea can provide. The exploitation and mining of minerals, other than sand and gravel, from the sea have just started. Most current activity is in shallow water. By 2020, 5% of the world's minerals, including cobalt, copper and zinc could come from the ocean floors. This could rise to 10% by 2030. Global annual turnover of marine mineral mining can be expected to grow from virtually nothing to €5 Billion in the next 10 years and up to €10 Billion by 2030 (Blue Growth Study, 2012). It may also become economically feasible to extract dissolved minerals, such as boron or lithium, from seawater. The most promising deposits however are found in metallic sulphides which emerge from hydrothermal ore deposits (such as 'black smokers') in volcanically active zones. The temperatures and pressures in these regions are extreme and the impact of disturbance on these hot spots of marine biodiversity, which under the UN Convention on the Law of the Sea (UNCLOS, 1982) should be protected, is largely unknown. Deep sea mining operations are currently mostly located within areas under national jurisdiction (exclusive economic zones and continental shelf) where it is easier to transport ores to land. However there are opportunities outside jurisdictional marine areas. In these areas, the International Seabed Authority (ISA) is responsible for organising and controlling activities, including monitoring all mineral-related activities. This includes protecting the marine environment in line with the provisions of UNCLOS, to which the EU and all its Member States are contracting parties. If this expansion of mineral extraction from the seafloor does take place, European companies, with their long experience in specialised ships and underwater handling, are currently well positioned to provide high-quality products and services. Their continued competitiveness depends on access to finance in an inherently risky market, targeted research and development in extraction techniques, the ability to obtain licences in international waters and robust measures to avoid harming unique ecosystems. The marine minerals sector will be able to benefit from the experiences of the offshore oil and gas sector here. EU support could include measures to ensure that European companies are not squeezed out of the value chain for marine minerals by state-supported competitors. This might include a pilot action within the framework of the proposed European Innovation Partnership on Raw Materials (COM, 2012, 82), supported by a structured EU research effort addressing main technology challenges. EU engagement would help to ensure that high environmental, legal and security standards are upheld (COM, 2012, 494 final).

5.4 Space mining

The business of space is growing rapidly. It is currently a $330 billion industry with accelerating growth. The number of new private companies being created to use space commercially is at an all-time high, with $13.3 billion invested in over eighty space startup companies since 2000. Continuing rapid growth of in-space businesses will increase the need for an in-space supply of propellants, life support materials, metals, and other commodities in order to support the sustainable expansion of Earth’s economy into space. The initial targets for mining are those objects that pass through Earth’s neighborhood. Many water-rich Near Earth Asteroids (NEAs) are in fact relatively easy to access as they travel around the Sun in very similar orbits to that of Earth. Additionally, these small bodies have very little mass, and therefore very little gravity, making it easy to leave the surface with the load of ore. As any other mining operation, Asteroid mining begins with prospecting for the best resources, mining and then transforming them into manufactured products. Deep Space Industries and its partners are developing end-to-end technologies to accomplish all these steps in the unique environment of space. Asteroid resources include all the same materials planets are made of, providing an abundant supply of exactly what we need in space. Specifically, C-group and related classes of asteroids contain high abundances of water and important elements, including organic carbon, sulfur, nitrogen, and phosphorus as well as ferrous, precious and technology metals.

Platinum Group Metals (PGMs) and Gold, for instance, are rare on Earth, but abundant in space. About 75% of NEAs are rich in Platinum Group Metals and some bear considerable amounts of gold. This is because, lacking the Earths active geology PGMs in space are as abundant as Tin and Lead and a single asteroid can yield up to 174 times the yearly output of platinum mining on Earth.

About 18% of known asteroids is easier to reach than the moon and prospect higher yields of valuable elements. Also returning from asteroids is easier for a matter of gravity (Ragheb M., 2013). SpaceDev, for example, has a plan to develop a mission known as the Near Earth Asteroid Prospector (NEAP). This low-cost mission (less than $50 million) would involve a 220 kg microsatellite launched as a secondary payload on a European Ariane 5 expendable launch vehicle. The mission objective is to land a payload on the surface of an asteroid as a demonstration of the potential for commercial asteroid mining (SpaceDev). Deep Space Industries, is similarly working on a $20 Million project to send a fleet of small scout robots to explore Near Earth Asteroids, mapping the different space objects and gathering samples for further composition analysis back on Earth (Ragheb M., 2013).

However, mining in outer space will require the development of new machines and robots in order to carry out mining operations at low or zero gravity and without an atmosphere. Therefore, many funds already are being invested in the development of ground breaking technologies for space mining, here on Earth. There is a list of potential applications for such technologies in potential future space missions. Finally in space, anaerobic bacteria and bio-mining could also represent a potentially viable extraction process (Ragozzine D., 2004). Nevertheless, the exploitation of such resources is a quite delicate matter, since the 1979 treaty confirms that extra-atmospheric space, including the moon and other Celestial Bodies (UNGA, 1979), cannot be property of any State and the resources therefrom must be equally accessible to the inhabitants of Planet Earth.

5.5 Space waste

As research forwards, space exploration is arousing increasing interest both for private and public companies. The increasing amounts of investments in the aero-space industry is already offering a wide array of commercial space travel products for scientific, industrial, entertainment and industrial purposes. The launch of space vehicles purposely released into the low earth orbit is however generating a new problem, which will soon pose major challenges to future space exploration. As a matter of fact Space Waste is becoming a serious issue. The so called geostationary orbit, which is the optimal position for telecommunication satellites is considered to be able to "hold" up to 1800 satellites. Currently there are a few hundred devices frequenting this area, and the "population" is growing rapidly. The multiplication of these space objects also increases the chances of collisions, which produce even more debris. States have promised they will "make an effort" to use the geostationary orbit in an efficient and economic "rational manner" in order to allow equal access to all countries to the resources of Space (Conforti, 2015, p. 327).

For fifty years, the primary source of all space junk came from objects that exploded by accident. However, in 2007, the intentional destruction of the Chinese weather satellite Fengyun-1C as part of an anti-satellite missile test created a significant amount of space debris. Two years later, a defunct Russian military satellite struck an operational American Iridium satellite over northern Siberia, blowing even more trash into space. Despite the small size of most of the objects, U.S. and Russian military are able to keep track of almost each piece of debris. Objects as small as 10 cm can be easily seen from Earth with radars an optical telescopes. When preparing a launch, mission controllers screen the predicted post-launch orbit for potential collisions in order to avoid as much damage as possible. Similarly, crafts such as the International Space Station (ISS), can change their orbits if a larger object approaches. yet there are always chances for potential collisions with smaller, untrackable objects that can still damage other space crafts. In fact, the region around Earth swarms with millions of pieces of man-made debris that create potential hazards to other functioning space-crafts and devices.

Since the launch of the Soviet satellite Sputnik in 1957 the orbits closer to Earth have been filled with large chunks of inert metal. Inactive satellites, upper stages of launch vehicles, discarded bits left over from separation, and even frozen clouds of water and tiny flecks of paint all remain in orbit high above Earth's atmosphere. When one piece collides with another, even more debris is released.

Over 21,000 pieces of space trash larger than 10 centimeters and half a million bits of junk between 1 cm and 10 cm are estimated to be orbiting our planet. This esitmate is only predicted to increase since there are also millions of pieces of debris smaller than 1 cm. In Low Earth-orbit, objects travel at 7 kilometers per second. At that speed, a tiny piece can have a tremendous impact. Not only can such an impact damage critical components such as pressurized cabins, solar cells or other equipment, they can also create new pieces of potentially threatening debris (NASA, 2016).

Earth's orbit is segregated into three distinct regions. Low Earth-orbit (LEO). Pieces of space junk in this region are impacted by the atmosphere, which degrades their orbit, dragging them back to Earth sooner. The lower the orbit, less time the object is likely to remain in space before returning to Earth.. NASA states that, on average, about one piece of space junk a day has fallen to the Earth over the last fifty years. Most pieces burn-up upon re-entry, those that don't typically end up in an ocean or a lightly populated area. According to NASA's Orbital Debris Program Office, no serious injury or significant property damage has been reported. Farther from Earth, navigation and communication satellites tend to prefer a semi-synchronous orbit 10,000 to 20,000 km above the surface. Telecommunication and weather satellites orbit in geosynchronous with the Earth's orbit, over 36,000 km high, and can virtually remain aloft for millions of years.

Cleaning the debris that already exists is a completely different challenge. Specific trips to larger objects could remove them from orbit, but at a high financial cost. Other proposals include the use of a laser to provide a “path-shifting push” that wouldn't damage the object.

CHAPTER

6

- Conclusion -

“...Development has made life much easier for millions of people, but has also wreaked terrible harm on the environment and caused millions more people to live in poverty. We have created a greedy materialistic society that has spread around the world. And our populations have hugely increased.

If we carry on with business as usual then the future for your children and all future generations is grim. […]

Think about the consequences of all the small choices you make: what to buy […] When billions of people think this way and make ethical choices the world will be a better place.

[...] We will realize that while we need some money to live, we should not live for money. That being happy is more important than getting rich. For the sake of the future of Planet Earth – your future – I hope you will work hard to make our dream come true. Before it is too late.”

Dr. Jane Goodall

Closing dump-sites and substituting them with simple systems with well-managed sanitary landfills and state of the art recycling schemes can bring a substantial change. It certainly requires alternative disposal projects, investments and know-how. However, a viable system requires much more: developing appropriate human resources and capacity building schemes to ensure proper control over such sanitary landfills; legal, institutional and administrative reforms must be put in place with an appropriate policy framework as well as efficient financial incentives. Moreover, promoting change will require tackling complex social issues especially in finding alternative and innovative solutions for the informal recycling sector. In order for this systemic shift to occur, radical and concurrent actions must be carried out simultaneously on all social, political, economic and technical scales. Current waste management systems and market conditions are incapable of handling the increasing amounts of waste generated worldwide. Unless a new paradigm of global cooperation and responsible governance is set up, the future of our planet is grim. Definitively, it is not exclusively about waste, since creating sound waste management systems worldwide can also play a fundamental role in eradicating extreme poverty. New patterns of international cooperation must be put in place in order to avoid a waste-full future for billions of people. We are already witnessing the e-waste stream flowing both legally and illegally towards the villages in China, India and Africa, turning them into horrific toxic dump sites. (Mavropoulos, 2016).

Thus, much depends on the choices we make every day. Our societal value today is that of consumers and as such we have great power. In this generalized erosion of sovereignty and increasing lack of credibility governments and politics have worldwide, it is time we, the people, the consumers, learned to make responsible choices in order to maximize efficiency and good practices while minimizing resource consumption and, most of all, waste. In the words of Leonardo Becchetti the best way to build a sustainable future is acting from bottom up and using the power we have as consumers to “vote with our wallet:” *«La forza decisiva per costruire dal basso un benessere equo e sostenibile sarà il “voto col portafoglio”. Ovvero la sempre maggiore consapevolezza dei cittadini* *che le loro scelte di consumo e risparmio sono la principale urna elettorale che hanno a disposizione» (Leonardo Becchetti, 2008*).

A wasteless future may defy the second law of thermodynamics (Sadi Carnot, 1824), expressed in the renowned Kelvin-Plank statement for which "*it is impossible to devise a cyclically operating device, the sole effect of which is to absorb energy in the form of heat from a single thermal reservoir and to deliver an equivalent amount of work*." Yet, given the knowledge we have, there is still ample room to greatly improve the efficiency of our economic system. The challenges we are facing call for prompt and cohesive behavioral change on behalf of us all, in order to guarantee a sustainable future for us and our offspring in the decades to come. Change starts from knowledge, therefore fostering education and raising widespread awareness play a key role in creating resource-wise citizens and professionals able to generate new business models in modeling the economy of the new millennium. The design process must be re-thought and re-designed on different principles, taking into account the entire life of materials from cradle to cradle, minimizing waste and our dependency on mining. Change hence starts from our everyday behavior and consumer habits. This calls for a deeper study of the relationships people have with their selves and their objects under many different aspects from psychology to philosophy, since only changing our relationship with ourselves, between one another and with the objects we possess can open to new perspectives and innovative designs and engineering.

In our contemporary society we identify with objects and our dependency from objects external to our being is fundamental both to our life and to our future. The clothes we wear to the technologies we use, in some sense, make us who we are as if we human beings had become a whole with these objects themselves. The subject therefore lives through its objects. ultimately, the distinction between subject and objects tends to fade and the subject cannot be thus separated from its objects without losing its identity (Cotnoir et al., 2014). Mereology is the theory of parthood, how parts interact with wholes and how parts interact with other parts. More generally, mereology studies the composition (Stanford, 2016) and metaphysics of structure (Harte, 2002). Perhaps mapping the mereological connections of our society, breaking down the parts and re-assembling the whole of our existence is part of the transformation which must occur in order to pursue our quest. The mereological analysis of our daily-life objects can reveal how our societies have grown increasingly more complex and interconnected. Likewise, the demand for materials we use to create such objects has grown as the social and economical consequences of the extractive industry have increased, often leading to conflict and environmental disasters. It is therefore necessary to map this fine patterned fretwork of parts and wholes in order to establish the relations and connections, which will eventually enable us to draw a road map to the best compromise between our societal goals and our planet, taking into account the economical and physical constraints.

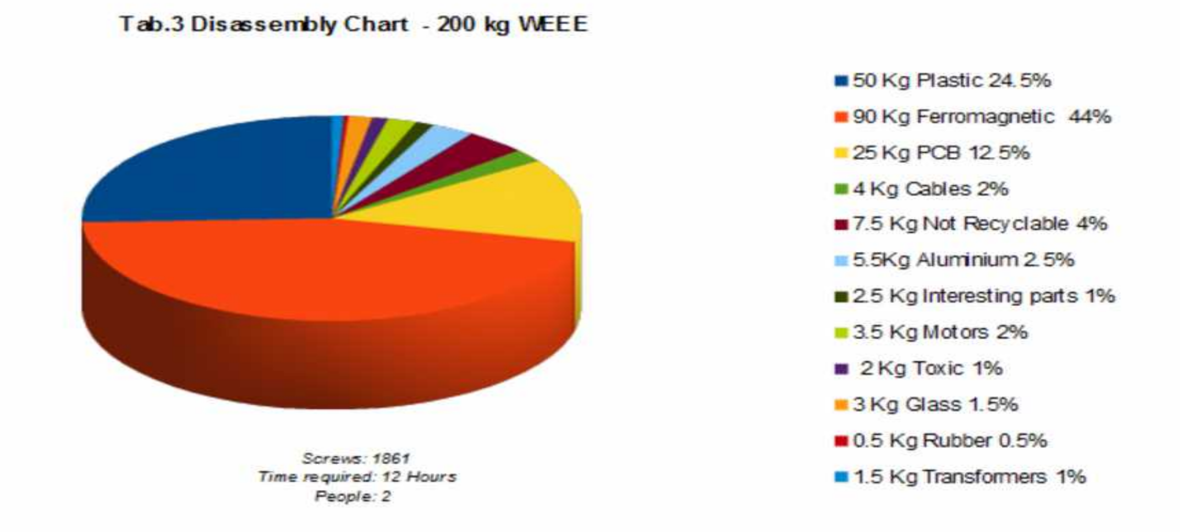
Profound analysis of society and the relations occurring between people, between people and objects and between objects begin with knowledge and understanding. Yet this knowledge also must have a bottom up component and thus much must be done in the field of vocational training and hands on education, since learning by doing and learning on one's mistakes is often the only path to develop innovative solutions. Thus using critical thinking and accepting that “we don't know anything” and all our certainties may be questioned Socratic debate, or maieutics, is in fact a form of cooperative argumentative dialogue between individuals, based on asking and answering questions to stimulate critical thinking and to draw out ideas and underlying presumptions. This is a dialectical method, often involving discussions in which the defense of one point of view is questioned, one participant may lead another to contradict themselves in some way, thus weakening the defender's point and opening to groundbreaking innovative solutions.

Example of practical Experience – WHAT WEEE ARE pilot project

This conclusive sub-chapter presents an innovative pilot project which aims at bringing together science, politics and art as a means to involve the general public in questioning their everyday behavior and therefore allowing for deeper reflections and informed consumer choices.

The project started by gathering e-waste abandoned on the streets of Europe mainly in Torino Italy, but a few parts were found also in, Belluno, as well as in Turku, Finland and Diessen am Ammersee and Berlin in Germany. Other waste was collected from friends and family, who gladly donated their old devices to support the project. In less than a year, the team composed by two people, put together about 200 Kg of e-waste. The composition of such e-waste comprised a vast variety of household and ITC items from vacuum-cleaners to desktop and laptop computers, mobile and land phones as well as kitchen and entertainment electronics.

This of two self-trained operators, one female and one male, carried out the operations wearing complete Personal Protection Equipment: full protective suits, goggles, rubber cut-resistant gloves, dust masks and steel toe shoes. The tools used were strictly hand-powered multi-head screwdrivers, pliers and scissors. For each object disassembled, the team would stop and weigh all the materials and count the screws. The total time employed for disassembling all 192,854 grams of waste, excluding pauses and the time used for weighing, counting and writing down the data, adds up to approximately 12 hours. That is 12 hours x 2 people = 24 man-hours. The results of manual processing are described in the chart below which was elaborated from the results of experimental disassembly. In particular, Printed Circuit Boards (PCB) represents an average 13% in weight of the total e-waste collected and processed, while ferromagnetic materials account for 44% in weight. Plastics are nearly 25% in weight, but represent more than half in volume.



The main drawbacks encountered during disassembling operations are related to the quantity and different size of screws used to keep the design together as well as for the presence of glues and/or heat sealed plastic parts. The study demonstrates that some 2000 screws were retrieved, averaging 10screws/kg, which makes disassembly considerably time-consuming. The use of glues, heat-sealing and rivets make disassembly somewhat tricky and potentially dangerous when involving glass and pointy geometries.

To resolve this it is necessary for producers to invest in design for disassembly, improving the simplicity of the designs still maintaining all the properties and mechanical qualities of their product. From this hands-on experience, it is clear that designs have already substantially changed within the last 20-30 years. However, according to brand and country of production/design there still are noticeable differences in the designs which greatly influence the easiness, safety and time required for manual disassembly operations.

The materials are then used to produce sculptures, textures and sets for the production of short animations videos in stop-motion. Up until now 2 videos have been produces and are now participating in Film Festivals worldwide. Finally the project offers artist residencies and workshops involving high school and university students in learning about technology and raw materuals. Currently the project is at its first year and has covered 2 schools in Italy, for a total of 3 classes; 1 School in Diessen am Ammersee, Germany and one University in Turku, Finland. The workshops consist in a 6 hour package: 2 hours of theory, 2 hours of disassembly and 2 hours of creative elaboration. During the workshop students and audience are asked to complete a WHAT WEE ARE survey. This survey is specifically developed to evaluate general consumer awareness over the issues regarding raw materials and precious metals in particular as well as investigates how much and where e-waste has been disposed of by the survey sample. Preliminary results underline a general lack of specific knowledge regarding fundamental aspects of critical raw materials and their importance in everyday life. In addition many of the people interviewwd declared that they store their broken electronics at home, in the cellar or in the garage and often they do not know where to correctly dispose of their e-waste and if they do, either they do not trust the recycling system, or they suppose their electronics may still be useful for some purpose in the future.

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