DELIBERABLE 6.4

Environmental Policy Brief

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Summary

CIRCULAR ECONOMY is the answer to an increasing growth waste generation, following the EUROPE 2020 strategy, aiming to a wise and sustainable growth, through a longer lasting life of goods, hence reducing the waste volumes.

The European WEEE Directive does partially follow this approach. But unfortunately only partially as it stresses the volumes to be treated in general. It does not consider the recycling of CRITICAL RAW MATERIALs, an important goal of the EU Raw Materials Initiative. This leads to a major focus of all the companies operating in waste domain on recycling large volumes at the lower cost possible.

A possible solution could be the introduction of “Critical raw material Recycling Certificate (CRC)”. For each critical/target material a number of CRCs will be fixed according to volumes. The certificates’ value will be linked to the actual cost of extraction not covered by the income of material sales. Such value will indeed vary in accordance to market conditions over time and phase out when break-even will be reached.

The collective systems supporting Circular Economy and specifically close the loop of critical materials will be able to buy CRCs from the recycling companies and by that enable the recycling activity for these target materials.

In the WEEE system there will be a “BONUS” for those collective systems buying CRCs to enable them to have certain benefits for the periods to come (e.g. a lower target volume for collection in the next period).

This approach will lead to both reduce the amount of waste and reduce significantly the environmental impact (mining activity, chemical synthesis of new polymers) by keeping the CRITICAL RAW MATERIALS within the E.U., inducing independence from non E.U. countries which at the present stage are in a monopolistic situation, increasing global sustainability, keeping WEEE treatment expertise and recycling companies in the E.U. and also keeping and even strengthening the skills and research to develop technologies and processes for the recycling and reutilization of Critical Raw Materials in the E.U.
1 Background information

Waste from Electrical and Electronic Equipment (WEEE) is the fastest growing waste stream in Europe. Worldwide figures are ranging from 20-50 million cubic meters e-waste. About 5% of the total waste stream can be derived from End-of-life Electr(on)ics. Therefore the EC implemented the so called WEEE Directive in order to ensure an environmental friendly treatment of end-of-life electrical and electronic equipment. In the European Union alone more than 17 million tons of electrical and electronics will become obsolete this year.

Rapid changes of consumer demands have affected that WEEE represents the fastest growing waste stream in the EU with between 3 and 5% per year, which means that it doubles every 12-15 years. On average every three years the IT equipment is exchanged by rapid growing turnover rates. Other electr(on)ic products are exchanged in average every 5 years. The life cycle of electr(on)ics is decreasing constantly, products are exchanged faster and faster. Obsolete electr(on)ic equipment ends up as e-waste which leads more and more to a global problem: With its complex composition of materials, components and hazardous substances, it constitutes a considerable threat to the environment. About 70% of the heavy metal in landfill is directly coming from e-waste. Next to that a reproduction of electr(on)ics needs about 10 times the final weight on abiotic natural resources (especially crude oil). That means that a TV set of about 50 kilos consumed about 500 kilos of raw materials during the production phase. Hence it is clear that landfilling of e-waste is an environmental crime. Countries all over the world therefore reacted and developed a legislation which should lead to a “greening” of e-waste.

Material diversity and strategic metals

Electr(on)ic products consist of a high amount of diverse metals. According to a survey of Sullivan e.g. mobile phones have a metal content of 25% (accumulator and recharger not included), mainly copper (Cu), iron (Fe), nickel (Ni), silver (Ag) and zinc (Zn). Though the absolute amounts of each device regarding the most valuable elements are low (16 g Cu, 0.35 g Ag, 0.0034 g Au, 0.015 g Pd, and 0.00034 g Pt) this adds up to e.g. 0.35 t of platinum based on estimated 1 billion of cell phones in 2010 (see also figure below).

![Figure 1: Elements in assembled Printed Circuit Boards](image)

Regardless of their low amount in specific electronic components there are some metals which are highly preferred or are even essential for the present technology. The most famous example is tantalum and niobium, which is processed from the ore coltan.
In 2010 the Raw Materials Initiative of the European Commission defined 14 critical raw materials, most of rare metals (including rare earths oxide) which are used for electr(on)ic devices belong to this category.

Most electr(on)ic relevant metals are mined in only 5 – 10 (non-European) countries, some of them in conflicting areas without “good governance”. CRMs recycling within Europe following today’s legislation guarantees minimization of the environmental impact caused by the recovery activities. The same is not always true for the mining activities outside Europe, e.g. due to poor waste management around the mines.

Furthermore, recycling of these “critical metals” will contribute to:

- the overarching goals / objectives of the proposed project
- minimizing the toxic burden on and around the sites of mining, processing and manufacturing
  - reducing the devastation of soil, natural habitat and other living conditions of as well human beings as endangered species of animals and plants
- cost saving for manufacturing (taking into account rising prices for most of minerals and metals respectively)
  - downsizing the dependency of permanent supply of essential resources from some non-European countries
  - supporting initiatives, resolutions and legal actions of the UN, EU, OECD and national governments for saving national resources and energy towards improving environmental protection.
- Not only saving jobs in Europe, but also creating additional green jobs and industries with high export potential.
2 Challenge

Since the industrial revolution the growth model “buy-use-dispose” has been the leading one as the belief of everlasting resources, easy to dispose and that would always lead to an End-of-Life for each product, also called LINEAR MODEL. However, the EU has definitely headed to a more sustainable direction in the last years, through an objective of waste reduction and recycling. CIRCULAR ECONOMY is the answer to an increasing growth waste generation, following the EUROPE 2020 strategy, aiming to a wise and sustainable growth, through a longer lasting life of goods, hence reducing the waste volumes.

This new policy has various reasons to be developed: greater global consumption of non-renewables, a progressive decrease of commodities, the lack of specific waste disposable areas, hence a need to reduce the amount of waste. Also the compulsory need to monitor the environmental health endangered by the waste reduction procedures and generally a much greater social attention concerning “waste” in general, but especially waste treatment (landfilling, incineration, …).

The transition towards CIRCULAR ECONOMY implies not only great changes in the production chain, starting from the design to the consumers’ attitude. This does imply a systemic change in technological innovation, logistic, in society, in finance, touching all the bullet points of GOVERNANCE.

CIRCULAR ECONOMY can indeed develop new markets with a different outlook through a redistribution of goods and an optimized utilization. The change from linear to circular economy has been rather easy and favored by the value of some commodities such as basic and precious metals – steel, aluminum, copper, gold, silver, platinum and so on- also thanks to new European regulations.

The European WEEE Directive does partially follow this chain. But unfortunately only partially as it stresses the volumes to be treated in general. It does not consider the recycling of CRITICAL RAW MATERIALs, an important goal of the EU Raw Materials Initiative. This lead to a major focus of all the companies operating in waste domain on recycling large volumes at the lower cost possible. This approach did not enable to identify the fractions of waste containing potentially important and valuable fractions, whose production from commodities is both expensive and environmentally harmful and complex. In addition some of the critical raw materials are currently mined in politically instable countries or even used as a political instrument by totalitarian governments.

In summary we can segment the current market in 4 sectors:

- A sector that is driven by the current WEEE legislation (upper left in following graph) because it is not economic by itself. This is the domain of collective systems.
- A sector that is economic by itself and therefore needs no legislation (lower right). That is the home of the “informal sector” in many emerging, but also developed countries.
- A sector that is both economical and covered under the WEEE directive (upper right). Here all players are active.
- And finally a sector that is neither economic, nor driven by the WEEE directive (lower left). This is the target of the new “Critical raw material Recycling Certificates (CRCs)” because there is currently nobody focusing on.
Within this sector the lost fractions belong to the following three categories:

- materials which do have a demand on the market, but at a lower cost
- materials potentially recyclable on the markets which do not seem to be well marketed and do not overcome the people’s diffidence
- materials which by now do not have validated treatment technologies and are still under research
3 Policy implications

The NON RECOVERY of such fractions is in contrast with the basic philosophy of CIRCULAR ECONOMY and moreover in total divergence with the recycling objectives of the CRITICAL RAW MATERIAL initiative which the European Commission has been implementing, advertising and sustaining economically in the past few years, also with financing facilities described in HORIZON 2020, and implementing further analysis in order to better finalize new guidelines and laws for the total of E.U. territory.

The recovery of these materials will lead to both reduce the amount of waste and:

1. Reduce significantly the environmental impact (mining activity, chemical synthesis of new polymers)
2. Keeping the CRITICAL RAW MATERIALS within the E.U., inducing independence from non E.U. countries which at the present stage are in a monopolistic situation
3. Increasing global sustainability
4. Keeping WEEE treatment expertise and recycling companies in the E.U.
5. Keeping and even strengthening the skills and research to develop technologies and processes for the recycling and reutilization of Critical Raw Materials in the E.U.

The European market and legislation have not yet been adapted to meet the needs of the secondary CRMs and their producers. Legal, societal and market barriers stand against the environmental and supply security reason. Technologies for CRMs recovery are applicable already today and recycling from e-waste stream is possible. Recovery technologies can concentrate the CRMs, improve their availability and reduce the amount of contaminants. Market entry of recycled CRMs is possible today, but there are legal and market complexities to overcome.

Having said that, it looks absolutely necessary to REBUILD all the rules and regulations which are now governing the WEEE system.

It is compulsory to identify, once and forever, a European panel governing on the whole territory in the matter of Critical Raw Materials, which at the present stage are dealt with at private companies, individual efforts, optimizing for the whole of Europe a virtuous process of Circular Economy (for example obligation for national or regional action plans for CRMs recovery in line with the European goals, implementing technical solutions, …).

In order to succeed, all producers have to gather the materials in a different “sorting” manner from what they have been doing up to date.
4 Possible solution: Critical raw material Recycling Certificate (CRC)

1. For each critical/target material a number of CRCs will be fixed according to volumes. The certificates’ value will be linked to the actual cost of extraction not covered by the income of material sales. Such value will indeed vary in accordance to market conditions over time and phase out when break-even will be reached.

2. The collective systems supporting Circular Economy and specifically close the loop of critical materials will be able to buy CRCs from the recycling companies and by that enable the recycling activity for these target materials.

3. In the WEEE system there will be a “BONUS” for those collective systems buying CRCs to enable them to have certain benefits for the periods to come (e.g. a lower target volume for collection in the next period)

Example:
Let’s assume a critical raw material A where the best available technology needs a benchmark price of 20 €/kg material A in order to reach break-even. Currently the market price (average price of the previous quarter) for material A is 15 €/kg which makes it uneconomic to recycle.

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<td>Lamps</td>
<td>1.000,00</td>
</tr>
<tr>
<td>Input powder processing</td>
<td>25,00</td>
</tr>
<tr>
<td>Resulting Rare Earth Oxalate</td>
<td>8,33</td>
</tr>
<tr>
<td>Processing costs</td>
<td>7,00</td>
</tr>
<tr>
<td>Revenue oxalate</td>
<td>2,50</td>
</tr>
<tr>
<td>Amount to be covered by CRC</td>
<td>4,50</td>
</tr>
<tr>
<td>Costs lamp treatment IT</td>
<td>800,00</td>
</tr>
<tr>
<td>Additional costs</td>
<td>37,50</td>
</tr>
<tr>
<td>% of current treatment price</td>
<td>4,69%</td>
</tr>
</tbody>
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First cost estimations to extract critical raw materials from different input materials:

- Lamps: 30-40 €/ton input
- CRTs: 0-5 €/ton input
- LCDs: 5-10 €/ton input

A collective system can now support for example with 10.000 € the recycling of 2 tons of material A. In return the collective system will receive 200 CRCs (10 kg per CRC) which will be taken in consideration by the clearing house when calculating the collection target for the next period.
An open and transparent discussion on acceptable costs, allocation of these costs, as well as transition timeframes and market entry need to be started now.

Pilot project in Italy:
This mechanism would be ideally both illustrated and authorized by Ministero dell’Ambiente and Ministero dello Sviluppo Economico and in test for one year in a program agreement signed by
- the RAEE coordination management company
- the Sistemi Collettivi
- specific Treatment plants

after having specifically focused on one or two significant fractions such as: Rare Earths, Lead Glass.

After the testing period in Italy, the Critical raw material Recycling Certificate (CRC) project will be extended to:
- other critical fractions such as plastic
- at a European level, with the involvement of WEEE Forum, EERA, … and maybe even funded under EU Life programme
5 Annex: Experiences in other projects

The European Commission invited several other projects in this area to an information exchange workshop “The working meeting on rare metals recovery from WEEE” that took place in Brussels on 16th September 2016.

All participating projects expressed similar concerns. Please find more details in the attached summary of Mr. Klimek.

Acknowledgement

The research leading to these results has received funding from the European Union’s Seventh Framework Program (FP7/2007-2013) under grant agreement 308549 (HydroWEEE Demo - Innovative Hydrometallurgical Processes to recover metals from WEEE including lamps and batteries).

The author would like to acknowledge all partners for their support in this project.
The working meeting on rare metals recovery from WEEE
Brussels, 16th September 2016

SUMMARY

The working meeting on rare metals recovery from WEEE was meant to gather the experiences of ten or so FP7 and H2020 projects related to this subject (managed by DG Research, DG Growth and EASME). In total about 30 participants were presented of which 17 external guests. Main focus was on how to make the recycling of rare metals a profitable business in Europe.

Opening word by the EC pointed at the multistage character of the rare metals recycling value chain and on some important demand side specificities: rather low manufacturer willingness to use secondary rare metals - esp. in view of (artificially) lowered prices of primary ones – and high quality requirements both creating a rather shallow, fussy market. Investment in rare metals recycling is risky as it is shown by a recent decision of Solvay to phase out their plants for REM recovery from low-consumption lamps in La Rochelle and St. Fons. This is something to be kept in mind when planning new research projects.

Quantitative data on rare-metals-containing WEEE

The supply side starts from reliable data on WEEE generated and collected in the EU. This topic has been presented by Dr. F. Magalini from H2020 ProSUM project, which strives to create easily accessible databases of critically selected information regarding this subject. Since only 35% of the WEEE is legally collected in the EU, the project undertook a really difficult task of looking at the subject down to the single part level. Indeed as it was stressed in the discussion, sound data on what quantities of rare metals are available for collection in which equipment, and actually even in which part of it, are necessary to plan the sourcing for a future recycling process and to assess its profitability. Keeping in mind the very low concentration of targeted metals in the WEEE and a huge geographical distribution of collection centres, we are merely touching here the "top of the iceberg" in material logistics that heavily influences the cost side.

The ProSUM project works a lot on harmonisation of data evaluation methodologies, terminology etc. It organizes open stakeholders’ consultation and feedback on its latest harmonisation document on October 18th, 2016 in Brussels, to which all the interested parties are invited. Intermediate results and quantitative data collected up to now will be also presented there.

Separation of valuables

The complexity of the rare metals recycling process and its influence on the recycling costs was broadly presented on the example of LED lighting products by Dr. O. Deubzer from FP7 cycLED project. Because of a progressive lowering of embedded value in these products the first hurdle is the cost of the separate collection, and often its quality, too. For lighting products good separation at source is not easy due to insufficient marking of components type - practically, even later when doing the manual disassembly the only useful indication on such a product is a warning of a mercury presence in it. The rest may rely rather on the staff experience.

Once the rare-metals-containing material reaches the recycler's plant, next step is its necessary concentration that is usually done via (costly) mechanical pre-treatment or (even more costly and actually not used in Europe) manual dismantling. This was perceived as the highest barrier in this project. Just because of it indium,
gallium, as well as less expensive lanthanides cannot be viably recycled, unlike metals of higher content like aluminium (heat sinks) or PGM (drivers etc.)

Dr. Deubzer pointed also on another huge difficulty in this process namely to the very cumbersome liberation of the phosphors from the chemically resistant silicone matrices of the converters. Due to this fact it was not easy to obtain the REM concentrate of high metal content, but their final product (obtained by Umicore) was acceptable as a raw material for Solvay RE refining process. However, this process can be viable only for the most expensive lanthanides like lutetium.

As alternatives to recycling in lighting products, Dr. Deubzer listed:

- efficient use of REM;
- substitution (e.g. OLED);
- high longevity and reliability (in reasonable limits – technologies get obsolete rapidly);
- using high power chips rather than mid power ones.

Innovative recovery processes and their profitability

A successful example of indium recovery was presented by Dr. Ainhoa Andueza from Recyval Nano project (Apologies from EC for the web connection problems on the start of the meeting!).

This project aims to develop a new approximation in the recycling of valuable metals through the development of a complete process for recuperation of indium, yttrium and neodymium from Flat Panel Displays (FPDs) and their subsequent revalorization in the production of Indium Tin Oxide (ITO), europium-doped yttria \( \text{Y}_2\text{O}_3: \text{Eu}^{3+} \) and Nd-Fe-B magnetic nanoparticles for high tech applications. Technologically the project is based on direct feeding the solvent-extracted metal solution into the flame spray pyrolysis (FSP) for the production of nanoparticles in one step. A technically optimized process was validated which can safely remove mercury and recover concentrated streams containing indium and yttrium (the latter in a lower concn.), in addition to other larger profitable fractions. According to the researchers, from the three targeted metals, only indium proved to be economically recoverable since its concentration after manual disassembly of FPDs was high and its price is high, too. Flat panel displays recycling line in the project can treat up to 900 kg/h of FPDs. In a year, this is 3658 tonnes of FPD wastes recycled. An industrial chemical extraction line based on the one developed in the project could obtain 420 kg indium and 4800 kg yttrium a year.

Based on predictions of 400 000 tons of FPDs wastes by 2015, Europe reserves of key RE metals in FPDs would be around 3500 tons of indium and 4800 tons of yttrium. Current European production of indium in 2014 was 88 tons. Yttrium is not produced in Europe.

In the discussion, researchers from other teams put into question the profitability of indium recovery from FPDs. A feedback from the originators of the above data will follow.

An interesting block of presentation was related to batteries.

Dr. Marcel Meeus, formerly Umicore's chief specialist in battery materials, now independent expert for EMIRI, presented the possibilities and prospects for rare metals recycling via pyrometallurgical and hydrometallurgical procedures, the former being currently most widely used in Europe, due to the flexibility of the process
regarding different metals and feedstocks (esp. accepting different sorts of WEEE, no special need for mechanical pre-treatment), manageable environmental impacts, safe operation, favourable economy of scale, good energy efficiency (even if the energy consumption is high). This is a closed-loop process (battery-to-battery), based mainly on the "copper part" of EU existing metal refineries' infrastructures represented on the "metal wheel": metals like Co, Cu and Ni can be recovered; REM – usually ending in a slag - can be still extracted via a proprietary Umicore+Solvay's hydrometallurgical process; for lithium which is also contained in slag, at a current price level, even if 40% of lithium consumption is due to batteries, no absolute need for its recovery and no viable recovery route exist nowadays. However, rather optimistic prospects for battery recycling in the nearest decade, due to the growing market for e-mobility and energy storage applications may increase the demand for lithium even by 300%. With new trends in battery system development most probably the cobalt content per battery may decrease while in total Li-ion technology will prevail at least until 2030 – before any new chemistry can appear in response to the growing interest in high-performance fast-chargeable batteries for e-mobility.

New opportunities in hydrometallurgical processes for batteries were presented by COLABATS project researchers: Dr. M. Foreman (technology) and Dr. E. Goosey (environmental and economic impacts). In this process, the deep eutectic solvent (DES) used for black mass leaching offers an ionic solvent milieu of better properties than simple aqueous solutions – and at an acceptable price. Via targeted solvent extraction processes this new hydrometallurgical option offers a finer separation among similar elements and large resilience to a contamination of the feed stream by e.g. Ni-Cd batteries, which need not to be sorted out anymore. Smartly selected commercially available ammonium, amine or organophosphorus extractants allow for a good separation of e.g. Ln³⁺ from Co²⁺ or Ni²⁺. The gain that comes from the improved selectivity of the proposed system (i.e. lesser number of separation stages) and from chemicals reuse may result in the end in a new viable technology that of course need to be demonstrated now in a bigger scale. Dr. Foreman mentioned also the idea of a mobile plant in the future.

In her presentation on economic and environmental aspects of the COLABATS process, Dr. Goosey pointed also at advantageous results of its environmental impacts analysis, and discussed the benefits and limitations of this new approach. One main obstacle can be the low level of concentrations that may negatively influence the throughput. Chemicals reuse is then essential for improvement of process economics, the more that the DES used is a "consumable" ternary system.

An industrial scale demonstration of hydrometallurgical methods was a topic of HydroWEEE Demo project led by ISL (Dr. B. Kopacek), focused on rare metal recovery from lamps/CRT/LCD displays powders, PCBs and batteries. A stationary plan constructed at Relight company site in Rho, Italy is able to process above 300 t/yr of powders coming from 10.000 t of fluorescent lamps or 150 000 t from Cathode Ray Tubes (TV-sets or computer monitors). Currently also a mobile version of the process is operated in Romania and another permit is expected in Italy. Dr. Kopacek presented also a similar RECLAIM project targeting large recyclers in which his research organisation SAT took part.

HydroWEEE Demo partners (ResouTech spin-off) were able to sell several batches of their recovered RE concentrate to Solvay, before the latter decided to phase out their RE activities due to business reasons. Currently, although new cooperation ties are being sought, there is no viable recovery route for this waste stream in Europe. On the other hand, rare metals from batteries, PCBs, spent catalysts and CIGS PV modules still can be viably recovered.

Prof. Gabriella Tranell (NTNU) – REECover project) discussed the achievements of REEcover project in recovery of heavy REE from ferric WEEE shredder fractions (and also from mine tailings) via their hydro/pyro
metallurgical upgrading, solvent extraction and innovative electrolytic reduction. Technical, economic and environmental performance assessment of the complete value chain for REE recovery from existing "standard" WEEE waste streams to mixed HREE alloys was performed.

As to the profitability of the process it was concluded that:

- HREE recovery from processed WEEE waste is possible but economically challenging with today's low HREE prices; 2-3 times higher prices would be needed to make it viable.

- The physical separation of waste will make the largest difference to HREE recovery (targeted extraction of HDD, acoustic units in mobiles, small electric motors etc. – magnets recovery from customers waste has only started) and overall economics (e.g. Apple’s take-back scheme, Hitachi technology of HDD recycling)

- For sustainable extraction, it is important to look at all the metals extractable from streams that are today sold to e.g. steel recycling. To get to the diluted rare elements, we need to design our recovery flowsheets with care so as to optimise economic value and avoid increased entropy.

Ways forward

The economic aspects pointed out in presentations were largely discussed among the participants, as the research teams were in fact confronted with the same problems of low viability of RE recycling business. According to Dr. Kopacek, the reasons for this are following:

- Too low prices for primary metals (China wants to keep monopoly on rare earth and kill new mining projects)

- WEEE Directive favours collection of “heavy” equipment (washing machines instead of mobile phones)

- WEEE Directive favours recovery of base metals (Iron instead of rare earth – no target quota for the latter)

Not going into discussion whether this list is exhaustive or not, let us look at the participants’ feedback to these three, as given in the discussion:

Prof. K. Binnemans (KU Leuven - Remaghic, RARE3 and EREAN projects) remarked that we must learn from history: what is happening at the moment with the low prices of the rare earths is a repetition of the historical events in the early 1990s when China became dominant in the rare-earth market. Until the 1980s the rare-earth production was dominated by Europe and the United States. We had the whole value chain from mining, separation of mixtures of rare earths, REE alloy production, to production of rare-earth magnets and lamp phosphors. Then China started to lower the prices of the rare earths to a level lower than production costs so that most of the American and European competitors went bankrupt, with the exception of a few ones such as Rhodia (Solvay). But Rhodia shifted its main production facilities to China. In this way, China got its monopoly (cf. heavy REM). By increasing the prices afterwards, China could recuperate the losses it made by dumping the rare earths on the market and it could even earn a lot of money with the rare earths, selling them at very high prices. The high prices and the supply risks have of course stimulated new commercial initiatives in the rare-earth market outside China. China does not like these competitors and it decreased again the prices dramatically. The consequence is likely to be the repetition of the story of the 1990s.
Dr. Magalini (ProSUM) remarked that indeed rare metals are not required to be recycled. Specific targets are lacking even if some metal refinery standards require certain recovery of alloy metals, too. (There is neither any recycled metal content requirements in products – comment WK). Negotiations between collection schemes organizations and the recyclers focus then on getting processed a maximum amount of waste for a given price.

Dr. Foreman (Colabats) pointed at the problem of "orphan waste" such as NiCd batteries that should be treatable in the same process as other battery waste. This is to reduce the effects of the failure of the sorting to be perfect on the recycling process. According to him, EU should reconsider the idea of having some stockpiling, even within existing hazardous waste landfills. This idea was supported also by Dr. D. Gardner (REMANENCE) and Dr. Deubzer (cycLED). REM stocks could be financed from an additional targeted landfill tax being in fact a tax on critical materials. According to Dr. Foreman, in order to favour landfill mining a landfill-mining company should never be charged for returning to a landfill the residual waste which cannot be recycled: if 1000 kilos of waste is removed from a landfill and of this 200 kilos is recycled, the 800 kilos of residual waste should not attract a landfill tax when it is returned to the landfill. A case can be argued that the organisation doing the landfill mining in this example could even be given a landfill tax credit for 200 kilos or perhaps even be paid a landfill tax refund for 200 kilos worth of waste.

To mitigate the risk of stopping the rare metals recycling business in Europe the HydroWEEE Demo consortium proposed an introduction of special credit certificates related to CRM-containing waste streams "forgotten" in current WEEE Directive. This covers potentially recyclable materials for which the recovery process exists but is not economically viable or is still under research or for which the market is too shallow at the moment. The consortium proposes a mechanism of Critical raw material Recycling Certificate (CRC) credits:

1. For each critical material a number of CRCs will be fixed according to volumes. The certificates’ value will be linked to the actual cost of extraction (BAT) not covered by the income of material sales. Such value will vary in accordance to market conditions over time and phase out when break-even will be reached.

2. The collective systems supporting Circular Economy and specifically close the loop of critical materials will be able to buy CRCs from the recycling companies and by that enable the recycling activity for these target materials.

3. In the WEEE system there will be a “BONUS” for those collective systems buying CRCs to enable them to have certain benefits for the periods to come (e.g. a lower target volume for collection in the next period)

In this way the recycled value of CRM would be translated into moderation of quantitative targets of collection schemes organizations.

Estimated extra costs would be as follows:

- Lamps 30-40 €/ton input
- CRTs 0-5 €/ton input
- LCDs 5-10 €/ton input

In a presented example of lamps, the additional credit costs related to their CRM content that would have to be paid by the collection scheme organization amount to 4.7% of normal treatment costs. Even if ultimately charged to the lamp buyers, this would hardly cause any noticeable price increase.
The consortium is planning to discuss this mechanism with the Italian Ministry of Environment and with the Ministry of Economic Development in order to test it for one year in a program agreement signed by

- the clearing house (Centro di Coordinamento RAEE)
- the collective systems (e.g. Remedia)
- specific treatment plants (e.g. Relight)

as a national pilot scheme - based on the recycling output.

After the testing period in Italy, the Critical raw material Recycling Certificate (CRC) project could be extended to:

- other critical fractions
- at a European level, with the involvement of WEEE Forum, EERA, ... and maybe even funded under EU Life program.

To avoid differences between countries, this mechanism should be then endorsed by the EC as a Europe-wide.

**Cooperation with developing countries in WEEE recycling**

A separate block in the meeting was dedicated to WEEE in Africa and other developing countries.

Countries like India have forbidden any shipment of WEEE to their territory and any exports are restricted. This is not alas a case with most of African countries. H2020 EWIT project represented by the Project Manager Dr. I. Capurso is a Coordination Support Action working on an e-waste implementation toolkit supporting the recycling and the secondary raw material recovery strategies in metropolitan areas in Africa (Kenia, Zambia, Cote D'Ivoire and S. Africa). With action plans for the African target cities, EWIT tries to influence the local actors in such a way that the current "survival" chain of informal recycling could be converted into a more normal value chain via a better information and organization of the business so that some intermediaries could be eliminated and the value distribution made more fair. According to the consortium this can also bring about the increase of the recycled material volumes, improvement in their quality and value, stabilisation of their output flows, better e-waste (and businesses) traceability, improvement of health conditions in e-waste picking and dismantling.

Cost increase would be compensated by an increase in the final value and less "value leakage" along the chain.

The stage-to-stage approach along the value chain, aimed at improving the recovery efficiency of this supply chain was also supported by Dr. Magalini in his second presentation, this time based on UNU projects with African countries. Pointing at inability to close the loop globally, he stressed the necessity to use the Best of the Two Worlds philosophy that is to make use of the complementarity of Europe's and Africa's mutual advantages, with the goal of ensuring bigger and bigger bring-back of recovered resources to the EU. This should not be done on the "take the best, dump the rest" principle, treating these countries once more like colonies, but as teaching African policy makers and mostly informal recycling sector how to valorise their own opportunities not only just their lower labour costs. This topic was continued by Mr. R. Smit, the Director of African Projects of Closing the Loop BV, an organisation shipping mobile phones from Africa back to EU to be correctly recycled by e.g. Umicore (20 tonnes shipped this year). He explained that African "informal collecting scheme"
is based on "you need it - you buy it", and not on "polluter pays" rule like in EU (what makes possible their 90%+ recycling rates in most of the recyclables). However, due to an enormous geographic distribution, small capitalisation, big number of intermediaries wanting to make their profit and – last not least – to the large extent of illegal practices, the supply stays too unstable for large European waste management companies to place their investments there (but does not discourage Chinese and Indian players). In the same time some people buy PCBs above the value of their metal content – and these materials are not officially shipped out of Africa (!).

Closing the Loop’s business is growing towards the break-even point by involving new countries and partnerships with others. It is to be seen whether large European waste management enterprises will be interested to support this sort of activity (or to propose a different business model). For the moment EU import of recovered materials from Africa seems to be only starting.

A more pro-active approach by the EU towards projects and operations in areas such as Africa would encourage more businesses like Closing the Loop to look for innovative business models that can help alleviate the environmental problem of WEEE in Africa, but also the EU problem with its illegal outflow.

**Conclusions**

In the final discussion opinions prevailed that no profitable recycling of many rare metals will be possible without a significant change in framework conditions, that could mitigate the adverse effect of Chinese price policy on REM market. The European Commission should take now – protective not protectionist - steps in order to avoid serious problems in five years and beyond, especially in view of ever rising demand that in the end will inevitably trigger a new price increase. Ideally, one common protective mechanism should be urgently adopted in all EU countries in order to cover the real costs and externalities related to the material concentration and processing - from the dispersed RE content in the collected WEEE unto marketable refined products at the end of the pipe. Also high-tech OEMs in the EU which apply RE-consuming technologies should become a main party in this dialogue, so that a true market for recycled RE products could exist in Europe (and not in Asia or USA). Participants discussed also the mis-alignment of policies and regulations between EU states, and between other states that deal with the EU. Having specific goods classified differently in different states causes biased statistics, and encourages illegal transports and practices.

On the other hand the meeting showed clearly that recycling cost factors (and ways to influence them) are only starting to be analysed along the value chain. This is why the proposed solutions tend to take these costs as granted and look for a mechanism of an additional bridge financing, rather than to optimize the level of these costs or their distribution (e.g. by improvements in collection systems, logistics, separation of rare-metals-rich products from the bulk of WEEE and their targeted dismantling here in Europe). Value chain’s bottlenecks, weak points and leak points should be addressed and the economy of scale in this segment of WEEE recycling should be reconsidered stage by stage, to avoid investing in lines that are too small to be profitable.

Last not least, high tech sector in Europe has to be maintained and constantly developed, and specialists trained in order to prevent our loss of competences and capacities in the years to come.

These all are topics for a further discussion within the rare metals recyclers’ community - in a constructive dialogue with OEMs and the relevant European Commission’s services.