EUROPEAN TECHNOLOGY PLATFORM ON SUSTAINABLE MINERAL RESOURCES

Contribution to European Innovation Partnership on Raw Materials

WP 1 – Developing new innovative technologies and solutions for sustainable raw materials supply

January 2012

EUROPEAN TECHNOLOGY PLATFORM ON SUSTAINABLE MINERAL RESOURCES

Foreword

The European Technology Platform on Sustainable Mineral Resources (ETP SMR) is actively involved in the support of the European Union's policies and actions related to non-energy extractive industries/minerals and metals supply.

Within the frame of the preparation of a proposal for a European Innovation Partnership on Raw Materials (EIP RM), a Working Group within ETP SMR was created in order to deliver a content-related contribution to Work Package 1 (WP 1) "Developing new innovative technologies and solutions for sustainable raw materials". This contribution was delivered as a Draft Experts Report in July 2011. The Draft Report was discussed at the ETP SMR High Level Group (HLG) in Wrocław, Poland in October 2011. It was decided that the Report (Annex A) should take into account the valuable comments made on the report (Annex B) to become an ETP SMR document. This task was to be carried out by ETP SMR Secretariat. Due to the extent of comments, the Secretariat itself had no capacity to make significant changes so additional experts were involved. After the internal consultation it was clear that these changes would have a severe impact on the Draft Report and would question copyright/authorship of the Draft Report. These concerns were presented at the ETP SMR Steering Committee meeting in December 2011 where it was decided that the Draft Report can become an official ETP SMR document and the comments were to be added as an annex.

The essence of the comments is the reorganization of the report with the matrix division between major types of mineral resources (metals, industrial minerals and construction materials) and the mine cycle (exploration, mining, processing, reuse/recycling and substitution) of primary and secondary raw materials. Comments are also seeking for additional information on one hand and shortening the report on the other. This is a delicate task without strong involvement of the authors that were/are not available at this point. They would most probably be available when asked by the EU Commission for a detailed explanation.

Nevertheless, the added value of the Draft Experts Report of WP 1 "Developing new innovative technologies and solutions for sustainable raw materials supply" is:

- Sound expression of interest of very important European mining/metallurgical companies to participate (in fact, to contribute financially) in collaborative R&D proposals/projects. The expressed interests cover almost all scientific/technical/commercial sectors within mining, metallurgy, and related fields.
- Identification of the main areas (scientific, technical, environmental, quality, etc) for potential projects. The identified subjects might be considered by the European Commission as a reference to include appropriate topics in the next calls of FP7 and FP8.
- The involved companies and organisations have shown real interest to develop innovative technologies to reach pilot plant demonstration level, and this point has to be seriously considered by the European Commission in order to support that kind of demonstration projects.

With the description above, the WP 1 Draft Experts Report together with comments form the ETP SMR position documents.

For the ETP SMR Secretariat
Slavko Šolar, ETP SMR Executive Secretary
Carlos Frías Gómez, Chief Editor of Draft Experts Report & ETP SMR High Level Group Member
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EUROPEAN TECHNOLOGY PLATFORM ON SUSTAINABLE MINERAL RESOURCES

Annex A: European Innovation Partnership on Raw Materials, Work Package 1 "Developing new innovative technologies and solutions for sustainable raw materials", Draft Experts Report, July 2011

European Innovation Partnership on Raw Materials

Work Package 1

"Developing new innovative technologies and solutions for sustainable raw materials supply"

A contribution from
European Technology Platform on
Sustainable Mineral Resources

Draft Experts Report

JULY 2011

NOTICE

This report has been elaborated under the umbrella of the European Technology Platform on Sustainable Mineral Resources. This is a draft document that will be further reviewed and approved by the High Level Group of the platform.

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CHAPTER I

INTRODUCTION, OBJECTIVES, STAKEHOLDERS

I.1. Introduction

The future raw material supply is a grand challenge for society at large. As globally more and more people are entering the middle-class, the need for mineral resources will continue to grow. The second major factor for the increasing demand of raw materials is the increasing world population.

In November 2008 the EU launched the Raw Material Initiative (RMI) to secure reliable and undistorted access to raw materials) as being *"crucial for the sound functioning of the EU's economy"*. The raw materials issues have since then been an issue in connection with the Presidencies of Czech (Prague Declaration), Sweden (Luleå Declaration) and Spain (Madrid Declaration). In the latter, it was stated that about 70% of EU manufacturing depends on minerals and also metals.

In the EU2020 agenda several flagship initiatives are presented that will contribute to smart, sustainable and inclusive growth in Europe. We endorse the viewpoint that EU radically need improve on innovation to stay competitive in the global world while minimising the environmental impact. We particularly commend the Commission for launching European Innovation Partnerships (EIP). If well planned and well managed such initiative will create a platform for innovations in technology, business models as well as the social innovations necessary to meet the challenges ahead.

The European Technology Platform on Sustainable Mineral Resources (ETPSMR) strongly supports the proposal by the Commission to launch an EIP on Raw Materials for the Modern Society with the aim to "*ensure a secure supply and achieve efficient and sustainable management and use of non-energy materials along the entire value chain in Europe".* The initiative is the right step at the right time. We trust that the partnership will make it easier for the mining, refining and recycling industries and academic bodies to participate in the European Research Area in an efficient and productive manner. We see the need to increase business and job opportunities while at the same time safeguarding biodiversity and the environment.

Based on the information provided by the Commission at the informal meeting Dec 9, 2010, ETPSMR took an initiative to arrange a common meeting with several technology platforms Jan 12, 2011 to discuss the EIP in general and the Work Package

1 in particular - *Developing new innovative technologies and solutions for sustainable raw materials supply.* At the meeting we shared comments and viewpoints from ETPs Construction, EuMat, ManuFuture, SusChem as well as several presentations from ETPSMR. At the same meeting several expert volunteered to take active part in preparing supporting documents for the EIP on Raw Materials. ETPSMR also participated at the workshop arranged by the Commission February 28th 2011 where a brief presentation of the progress of the Work Package 1 (WP 1) was presented.

This particular report is our contribution to the WP 1. The main focus of the work has been on the ten pilot/actions plants proposed. Dr Carlos Frias, Tecnicas Reunidas (Spain), has been the leader of this task on behalf of ETPSMR.

I.2. Aim of this Report

The report is a compilation of input received from the interested stakeholder during January – June 2011. The Chapter 2 outlines the challenges ahead as we view them. The Chapters 3 and 4 outlines the European raw materials dimension with a focus on the critical materials as defined by the Commission. The main work done is presented in Chapter 5. Based on discussions at a workshop arranged in Budapest March 8, 2011 and further consultations with the Commission, several ideas for pilot actions have been identified along the value chain. The proposals included in this report all have a strong industrial/academic support and would contribute to the future success of the EIP on Raw Materials. These proposals were shortly presented and discussed at the ETPSMR workshop May 4th.

Several experts finally shared the work to compile this summary report. The contributors to this report and the partners involved in WP1 activities are listed in the Annex1. The first draft version was ready for review on June 2011 and this final draft version is issued in July 2011 after including the changes proposed by WP1 partners; the final approval is expected by the ETPSMR High Level Group in October 2011.

The setting up the EIP is a tremendous opportunity and responsibility and ETPSMR hope that this report would provide valuable input into the process.

ETPSMR view itself as a partner in the proposed EIP on Raw Materials for a Modern Society. As shown here, ETPSMR has prepared and coordinated inputs from several technology platforms, associations, universities and industries and other stakeholders and as partners we are strongly committed to contribute to the decision process as well as the future success of the EIP.

CHAPTER II

STATE OF ART

This Work Package 1 (WP 1) aims to develop innovative technologies/solutions along the entire value chain for cost effective, safe, environmentally and socially sound raw materials, including primary and secondary sources.

In the next figure II.1 is represented the whole value chain covering from raw materials extraction to marketed products:

FIGURE II.1. The entire value chain for raw materials

It is remarkable that scope of this WP 1 covers all the value chain except the substitution part, which is covered under WP 2.

II.1. Raw Materials Extraction

Underground mining in Europe has already reached a high standard in safety, sustainability and a fair degree of automated processes compared to the rest of the world. The mining concepts are well suited to the particular situation but the environmental footprint caused by mining operations over the production life still requires significant improvements.

Research into intelligent mining has been carried out for more than ten years yielding relevant achievements that have been recognised worldwide.

The world's mining industry faces a number of challenges due changes in demand and future perspectives especially in China and other emerging economies. As a result, mining, refining and recycling companies are under increased pressure for further rationalisation that requires both new technologies and new organisational solutions.

On the longer-term, environmental issues and the impacts of the Kyoto Protocol will significantly affect the sector. Any current and especially future mining must not endanger the health and welfare of local inhabitants. After mine closure, there should be as few traces as possible remaining in the environment. The only desirable track is a stable social infrastructure and a flourishing society that continues when mining ceases. A more specific challenge is identified in the Kyoto Protocol with regard to regulating greenhouse gases, especially carbon dioxide. This will require significant investments in the acquisition of emission allowances. Another factor to consider is the availability of water, especially clean water, which is a prerequisite and is not an obvious asset in all regions.

An important component of good working conditions is a safe environment. In underground mining, the basic solution must be to distance the miners from the physical mining front and locate them in a safer environment. Remote control, automation and new mining techniques are major challenges and possibilities, but it is also a matter of relevant education, rules and good practices.

Another challenge is the problem of recruiting skilled workers to the mines. Those are often located far from larger communities. A modern mine is so technically advanced that the proportion of unskilled labour will decrease significantly or disappear. There will be fewer workers with higher individual wage costs. Most mining companies want to avoid a "fly in – fly out" situation, as it could create social instability of societies and cause trouble in the workplace. This requires an organisation of the work that supports both high productivity and good working and social conditions.

Further challenges arise due to the fact that the mining industry is global and the major mining companies operate in many different countries. Managing a variety of local cultures is important for companies to have a good practice and a stainless image if a country's natural resources will be extracted. Additionally, to break the unequal gender balance that exists in most mines will be challenging.

Abrahamsson, Johansson and Johansson[1] gave a comprehensive overview about the challenges the metal mining sector faces in the upcoming years and even decades. This overview reported about several conferences and events dealing with future mining issue all over the world. Although targeting on metal mining, the statements are in general common to all mining sectors as well.

Summarising some of the sixteen predictions put forward in the article, the main challenges of the mining sector, among others, are:

- New deposits will be found at greater depths bringing in new stability issues. The role of rock mechanics in the design of layouts, cutting sequences, strata stabilisation, roof bolting etc. must be a central issue for the future.
- Raising environmental requirements in terms of both energy consumption and waste management. Mining industry is an energy-intensive industry with high CO_2 emissions. Improvement of energy efficiency will increase the economic profitability as well as reducing the environmental impact.
- The environmental debate also includes a discussion on the mining industry's social responsibility for the welfare of the local community. In addition to preserving the environment, they are required to build a strong technical and social infrastructure that ensures survival of society after mining is decommissioned.
- Increased requirements for the "automated mine" requiring design layouts and operations to suit automation and not as today, adapting conventional designs and operations to automation.
- Significant efforts to develop communications systems for increased security have been made. Integration of communication and process control will become

[1] Abrahamsson, Lena; Johansson, Bo & Johansson, Jan "Future metal mining – sixteen predictions. An analysis based on three international mining conferences". International Journal of Mining and Mineral Engineering (IJMME) (2009).

more and more important. Different types of machine-machine communication will grow in use.

Further to this comprehensive overview of the current and possible future situation of underground mining, a couple of other initiatives have been or are still on the way world-wide dealing with the mine of the future. The Swedish conceptual study "Smart Mine of the Future"[2], which delivered its results in November 2010, came to similar statements as mentioned above. Among other issues, the study stated the need for continuous mechanical excavation, no human presence in the production area, pre-concentration and resource characterisation. The initiative will now continue with feasibility studies under the title "Smart Mine of the Future".

The CSIR (RSA) "Future Mine" project is a continuation of "DEEPMINE" in the area of occupational health and ergonomics. It also tackles issues for deep mining mechanisation, automation, communication and sensors. CSIRO Earth Science and Resource Engineering Division in Australia investigates into sustainable mining systems, mining automation, mining geoscience and next generation mineral mapping. Finally, DMRC, the Canadian Deep Mining Research Consortium currently runs projects defined by the current challenges of deep mining in Canada.

Today, the deepest European underground mines operate at about 1,000 to 1,500 meters below surface. According to their different geological conditions, alternative mining systems are used. On one hand, we find hard rock formations with thin, deep, steep ore bodies, which are mined by sublevel caving or - stoping methods. For those mines having ore bodies that are steeply dipping, mainly located in Scandinavia, their operating depths increase rapidly. Within the next 20 to 30 years, several of those mines will operate at depths far below 1,500 meters.

On the other hand, Europe's flat bedded layer deposits follow seams of coal or potash. Those are now mined at great depths and are facing increased challenges in countries like Poland or Germany. Surface stability criteria imposed by countries are greatly affecting the mineable reserves (massive extraction losses) due to dimensioning

[2] MIFU: Smart Mine of the Future – Conceptual Study 2009-2010, Final Report, Rock Tec Centre, Sweden November 2010

requirements of pillars to maintain minimal surface subsidence. For all different mine types there are common problems when reaching great depth formations. The main objective should be to develop potential new mining and processing methods for mining of those deep, steeply dipping hard ore bodies or flat soft rock seams at depths below 1,500 meters. These depths will cause increasingly difficult mining conditions. Therefore, there will be a need for developing new mining methods to maintain safe working conditions, increase productivity and production rates, and reduce waste and tailings as well as mining costs to maintain competitiveness on international markets.

The concept of the “invisible, zero-impact mine” aims at zero impact of mining activities above ground and as little as possible impact underground. This will only be possible by moving installations from the surface to underground (mainly processing plants and waste deposits will be shifted underground, social buildings and logistics facilities will obviously remain above ground) and implementing a complete new layout of the mine of tomorrow. Given that in the future underground mines have to access and extract mineral deposits at increasing depths in order to maintain and even enhance mineral production in Europe, we will need innovative technologies in every part of an underground mine.

The mine of the future, which has to exploit mineral raw materials at greater depths than today, requires a completely different layout compared to today’s deep mines. This includes communication, planning and decision making tools as well as machinery for extraction, transport and processing systems that are suitable to deal with the conditions expected at depths of some 1.5 km and beyond. Breakthrough technologies for autonomous, highly selective, continuous mineral extraction processes and machinery based on new sensor technologies, face-front separation as well as innovative concepts for mass flow management and transportation integrating all beyond state-of-the-art technologies are necessary in the complex mining environment. These developments include rock mechanics and ground control solutions and incorporate the health, safety and environmental issues as well.

The concept of an invisible, zero-impact mine requires a refined process underground that selectively mines the minerals and therefore reduces waste production closer to the mineralisation. For this reason, improved near-to-face processing methods including backfill procedures need to be developed. The necessary level of automation in mining operations regarding also health and safety and logistics issues can only be achieved by reaching a higher level of integration in all parts of a mine. Fully integrated underground technologies and processes for diagnosis and extraction as well as communication, health and safety issues are the key for the success of the concept.

II.2. Scarcity of Raw Materials

There is nothing new in a statement that in most of the cases mineral and metal resources in Europe are not able to provide self-sufficiency of European economy. It especially holds true when considering base non-ferrous metals, such as copper, zinc, lead and nickel. According to the data of 2010, in 27 EU countries 783,000 tons of copper were extracted[3]. In the same year metallurgical production of that metal was 2,680,000 tons, while its consumption reached the level of 3 299 000 tons. That means that European extraction covers only 29% of the demand for concentrates necessary to meet the requirements for production in metallurgical plants, and also import of metallic copper is necessary. A similar situation can be observed with nickel. EU27 consumption of that metal is at the level of 295,000 tons, while its production from primary materials is 81,500 tons only (data of 2009[4]). Zinc production – over 2 million tons per year – is over twofold higher than zinc mass produced in a form of concentrate. Therefore European zinc smelters need to import over 50% of their charge material. Lead consumption of 16m tons is covered by European production of the concentrate from primary resources in 23% only.

The situation with lead is significantly better because of high level of lead production from secondary materials, mainly from lead-acid battery scrap. In Europe 100% of that material is recycled, which means annual production of 1m tons of lead. In that case there is also a need to import about 300,000 tons of the material per year. International Lead and Zinc Study Group foresees further increase of European zinc and lead consumption of minimum 3% per year[5].

[3]Mining Journal , 2010, Oct.8, p.7
[4]www.insg.org
[5]www.ilzsg.org

The above facts clearly show the dependency of European economy on import of raw materials which contain base non-ferrous metals, while their availability is becoming more and more insecure. The Commission in its document[6] states that scarcity of geological deposits is not the reason of that situation. The actual reason results from political and economical changes in the contemporary world and especially from the rapid growth of economies of the countries in Asia as well as from more often observed restrictions in free trade.

The base non-ferrous metals are not included in the group of 14 materials which were defined as critical, however at least two of them (zinc and nickel) are very close to that group, because of their increasing economical significance, while the third one – copper – is also characterised as a metal of high economical importance. It needs also to be emphasized that some of the critical metals do not occur in isolated deposits of their minerals and are produced in a form of by-product metals in production of basic metals (indium – lead, germanium – zinc, gallium – aluminium, cobalt – nickel, as well as significant mass of Platinum Group Metals recovered in production of nickel and copper).

Even small changes in parameters which were applied in selection of critical metals can significantly change the classification. Therefore it was suggested to periodically review the analysis of availability and criticality of mineral resources[7].

Intensification of geological exploration is one of the most important factors in increase of potential for development of raw materials sector. So far it was not very intensive. In the group of 10 leading countries of the highest spending on exploration there is not a single one from the EU27[8]. Some changes in that respect have been recently observed. Two Nordic countries, Sweden (Strategic Mining Research Programme in an agreement between the Swedish Agency VINNOVA and MITU) and Finland (Finland's Minerals Strategy) have initiated national plans for development of mineral, especially metallic, resources. Drilling is also conducted in Fore-Sudetic monocline in Poland and

[6] Critical raw materials for the EU, European Commission Enterprise and Industry, 30 July 2010
[7] Communication from the Commission to the European Parliament and the Council, The Raw Materials Initiative – Meeting our critical needs for growth and jobs in Europe, {SEC(2008) 2741}
[8] Don Smale. 'Current situation and prospects for copper, nickel, lead and zinc', Global Commodities Forum, Palais des Nations, Geneva, 22-23 March, 2010

Germany. Both mentioned above EC documents call for intensification of geological exploration and strong cooperation of national geological surveys in that area.

Currently available geological data shows existence of many base metal deposits in Europe, however in some of the cases the deposits are of polymetallic and, therefore, low-quality character. There are deposits in Iberian Peninsula which contain about 500 million tons of the ore with copper, zinc and lead concentrations of 2%, 2.5% and 1%, respectively. Similar deposits can also be found in other parts of Europe. Complex character of the ore requires development of new technologies for its beneficiation as well as for further pyro- and hydrometallurgical treatment. Worldwide experience shows particular applicability of hydrometallurgical and bio-hydrometallurgical methods when addressing such problems.

Both research and industrial activity should at the same time focus on recycling of metals. Currently lead presents an excellent success story in that respect; however, it is concentration of its consumption in production of lead-acid batteries which creates favourable conditions for the recovery. Recently coined term "urban mining" confirms that problem of collecting, mechanical and metallurgical treatment of spent consumer goods of increasingly more sophisticated functions, structure and, therefore, constructed from non-standard and rare materials becomes more and more important and can relieve symptoms of scarcity and not full accessibility of critical mineral resources. Secondary resources in a form of flotation tailings and various types of metallurgical waste, such as slag, present another but also very important issue which is already addressed but needs further studies. To make those resources available it is necessary in the first step to make an inventory of such deposits. To make the recovery profitable and reach high recovery rates it is necessary to conduct intensive studies into development of technologies for beneficiation of minerals, mainly of oxide character, which are not susceptible to classical methods such as flotation.

II.3. Raw Materials Recycling

Mineral resources and the manufactured products incorporating them are vital inputs to the European economy and competitiveness. They are vital to the production of a very large range of equipment and services in sectors as various as aeronautics, car manufacturing, energy production, and information and communication technologies. The constant stress on primary resources supply may considerably jeopardize the activities of many sectors. It is particularly true for high-tech industries of which innovations require a growing use of scarce metals. Closing the loop through increased recycling from waste is an essential part of the response to securing Europe in strategic raw materials supply through the main assets:

- a reduction of the dependency on imports and the related risks,
- a more sustainable policy in decreasing the exports of wastes.
- an increased contribution to resource efficiency.

Sectoral European associations (e.g. Eurometaux[9]) state that EU non-ferrous metals industry is the world leader in most aspects of recycling:

- between 40 and 60% of Europe's metals output comes from recycling.
- the recycling efficiency of available metals is 60-90%.
- the EU non-ferrous metals industry is a leader in the recycling of base metals (e.g. aluminum, copper, lead, nickel and zinc), precious metals (e.g. gold, silver and platinum) and high-tech metals (e.g. selenium, titanium, cobalt, and tungsten).
- the scope of activity of several European metallurgical companies is a unique feature that has enabled the development in Europe of complex, inter-related processing flow sheets, making European non-ferrous metals recycling the most versatile in the world.

However, this brilliant picture is threatened by distortion in competition at international level. "The situation today in Europe is, however, very worrying. Despite all these environmental and economic assets, the future of metals recycling is under great threat. The competitiveness of this industrial activity is rapidly deteriorating due to excessive regulatory constraints and international trade and competitive distortions. If

[9] www.eurometaux.org

urgent action is not taken to remedy this situation, this activity will simply disappear in Europe" [10].

The experts of the Raw Materials Supply Group met at the request of the DG Enterprise and Industry of the European Commission shortlisted fourteen raw materials that are particularly critical to the European economy[11] signifying a high degree of both supply risk and economic importance. Rare earths, rare metals and metalloids including cobalt, niobium, tantalum, beryllium, magnesium, gallium, germanium, tungsten, indium, and platinum group metals represent the majority of these substances. This group of experts recommends that policy actions are undertaken to make recycling of raw materials or raw material-containing products more efficient, in particular by:

- mobilising End of Life (EoL) products with critical raw materials for proper collection instead of hoarding them in households (hibernating) or discarding them into landfill or incineration.
- improving overall organization, logistics and efficiency of recycling chains focus on interfaces and system approach.
- preventing illegal exports of EoL products containing critical raw materials and increasing transparency in flow.
- promoting research on system optimisation and recycling of technically-challenging products and substances.

At a global scale, UNEP (United Nations Environment Programme) stresses the limited recycling rates of metals. It is established[12] as shown at the figure II.2 below the EoL recycling rates of many metals are very low because:

- of increases in metal use over time and long metal in-use lifetimes, many recycled content values are low;
- of relatively low efficiencies in the collection and processing of most metal-bearing discarded products;

[10]Recycling-An integral part of the metals industry. "Recycling", 2005, European Association of Metals
[11]http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf
[12]Recycling Rates of Metals: A Status Report. Second report of the Global Metal Flows working group of the International Panel on Sustainable Resource Management of UNEP, May 2011. http://www.unep.org

- of inherent limitations in recycling processes and that
- some primary materials are relatively abundant and low-cost (thereby keeping down the price of scrap).

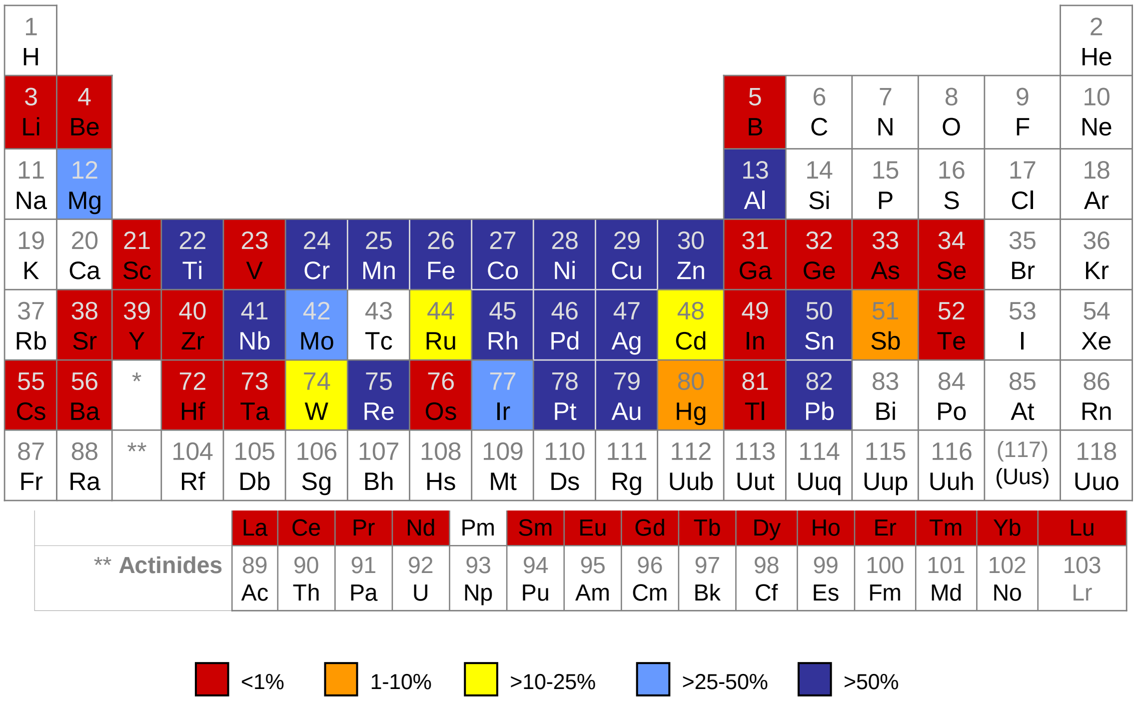

FIGURE II.2. The periodic table of global average end-of-life functional recycling (EoL-RR) for sixty metals. Unfilled boxes indicate that no data or estimates are available, or that the element was not addressed as part of this study. These evaluations do not consider metal emissions from coal power plants. The figure and the caption are copied from the report of which references are given in footnote 12

Even if comparisons of recycling contents across metals are problematic due to different growth rates in metal use over time, different end uses with different respective lifetimes, different production processes (sometimes limiting the amount of scrap used), and varying tolerances in metal production to scrap impurities.

An emblematic issue is about e-waste generated by electronic appliances that need a growing variety of metals to reach ever higher performances for more people every day.

The issue of E-waste management is particularly critical in the developing countries that have a steeply growing demand in electronic devices and not the entire capacity to deal with the wastes that it generates. UNEP has undertaken a study to evaluate the potential transfer of innovative technologies in the recycling sector[13]. The technical report of this study[14] released in 2009 cites a variety of sources to illustrate growth of the e-waste problem among the following ones:

- Global e-waste generation is growing by about 40 million tons a year.
- Manufacturing mobile phones and personal computers consumes 3 per cent of the gold and silver mined worldwide each year; 13 per cent of the palladium and 15 per cent of cobalt.
- Modern electronics contain up to 60 different elements - many valuable, some hazardous, and some both.
- Carbon dioxide emissions from the mining and production of copper and precious and rare metals used in electrical and electronic equipment are estimated at over 23 million tons - 0.1 percent of global emissions (not including emissions linked to steel, nickel or aluminum, nor those linked to manufacturing the devices).
- In the US, more than 150 million mobiles and pagers were sold in 2008, up from 90 million five years before.
- Globally, more than 1 billion mobile phones were sold in 2007, up from 896 million in 2006.
- Given the infrastructure expense and technology skills required to create proper facilities for efficient and environmentally sound metal recovery, the report suggests facilitating exports of critical e-scrap fractions like circuit boards or batteries from smaller countries to OECD-level, certified end-processors.

[13] http://www.unep.org

[14] Recycling from E-waste to Resources - Sustainable Innovation and Technology Transfer Industrial Sector Studies, UNEP, July 2009, by Mathias Schluep, Christian Hagelueken, Ruediger Kuehr, Federico Magalini, Claudia Maurer, Christina Meskers, Esther Mueller, Feng Wang

The Environmental Protection Agency estimates that only 15-20% of E-waste is recycled, the rest of these electronics go directly into landfills and incinerators[15].

Another important aspect in the criticality of some rare metals lies in the fact that some of them play an important role in green technologies that contribute to reducing greenhouse gas emissions and improving energy efficiency. As an example, the recovery of various compounds of rare metals from low energy bulbs after use represents a growingly economic challenge as well as an environmental concern in the management of the end of life products. Another example is cerium, which is used as a fuel additive to reduce auto emissions as well as in touch screens and solar panels.

Within the limits imposed by thermodynamics, two main technical bottlenecks must be overcome to reach a convenient level of sustainability of the processes of recycling. The first is to separate the components of the metal-containing wastes to concentrate the metals in streams of materials that can then be technically and economically processed to extract pure metals or compounds. The second is to ensure the efficient recovery of the latter to produce new raw materials for the industry.

The production of concentrated materials by physical processes inspired from ore processing techniques in a reliable way applicable to the majority of end of life products is the greatest challenge. The recovery of recyclable raw resources can generally be achieved by pyrometallurgy, but other kinds of treatments using hydrometallurgy or/and bio-hydrometallurgy may reveal to be more efficient and sustainable.

[15]http://en.wikipedia.org/wiki/Electronic_waste#cite_note-unep.org-3

WP 1

CHAPTER III

RAW MATERIALS AND CRITICAL MATERIALS (EUROPEAN DIMENSION)

Raw materials are essential for the functioning of the economy of industrialised regions like the EU. Sectors such as construction, chemicals, automotive, aerospace and machinery are completely depended on access to certain raw materials. In this respect, EU has to secure reliable and uninterrupted supply of raw materials and achieve sustainable and efficient management of non-energy raw materials.

The global demand for non-energy raw materials has experienced an unprecedented growth in the 20th century, with the United States and Europe being the dominant users of raw materials. During the last 50 years the production of steel increased six times, the production of copper increased fourfold, and aluminium production by seven times. However, since 1990 the global mineral raw materials demand is characterised by a notable increase, mainly by the so called BRIC economies, with the acronym standing for Brazil, Russia, India, and China. It is predicted that by 2040 the combined economies of the four BRIC countries will be larger than the combined economies of France, Germany, Italy, Japan, the United Kingdom, and the United States. At the same time China has become a dominant consumer and also a major supplier of raw materials. The increasing demand has significantly raised mineral and metal prices over the last 10 years.

The present situation in the global market of mineral raw materials is characterized by the:

- increasing demand for minerals from both industrial and developing countries,
- dramatic changes in where minerals come from,
- volatile markets and pricing, and
- increased vulnerabilities in the mineral supply chain.

Moreover, the geographically uneven distribution of earth's mineral resources and the almost full utilisation of sizeable and high grade deposits in Europe, dictate that the supply of raw materials at reasonable prices represents one of the greatest challenges for the EU in the 21st century.

In this frame, EU is in a particularly vulnerable position, for the following main reasons:

Europe is highly dependent on imports for many raw materials (e.g. EU produced only 3% of the world metal production) which are increasingly affected by growing demand pressure from: (a) emerging economies and by an increasing number of national policy measures that disrupt the normal operation of global markets (e.g. China as the world leading producer and rapidly increasing consumer of rare earths has declared most rare earth elements (REE) and products to be strategic commodities and placed new restrictions on foreign investments in this sector and exports on a series of REE); (b) emerging technologies (e.g. tantalum use in cell phones; indium, gallium and tellurium use in solar cells). The main import sources for EU are presented in figure III.1.

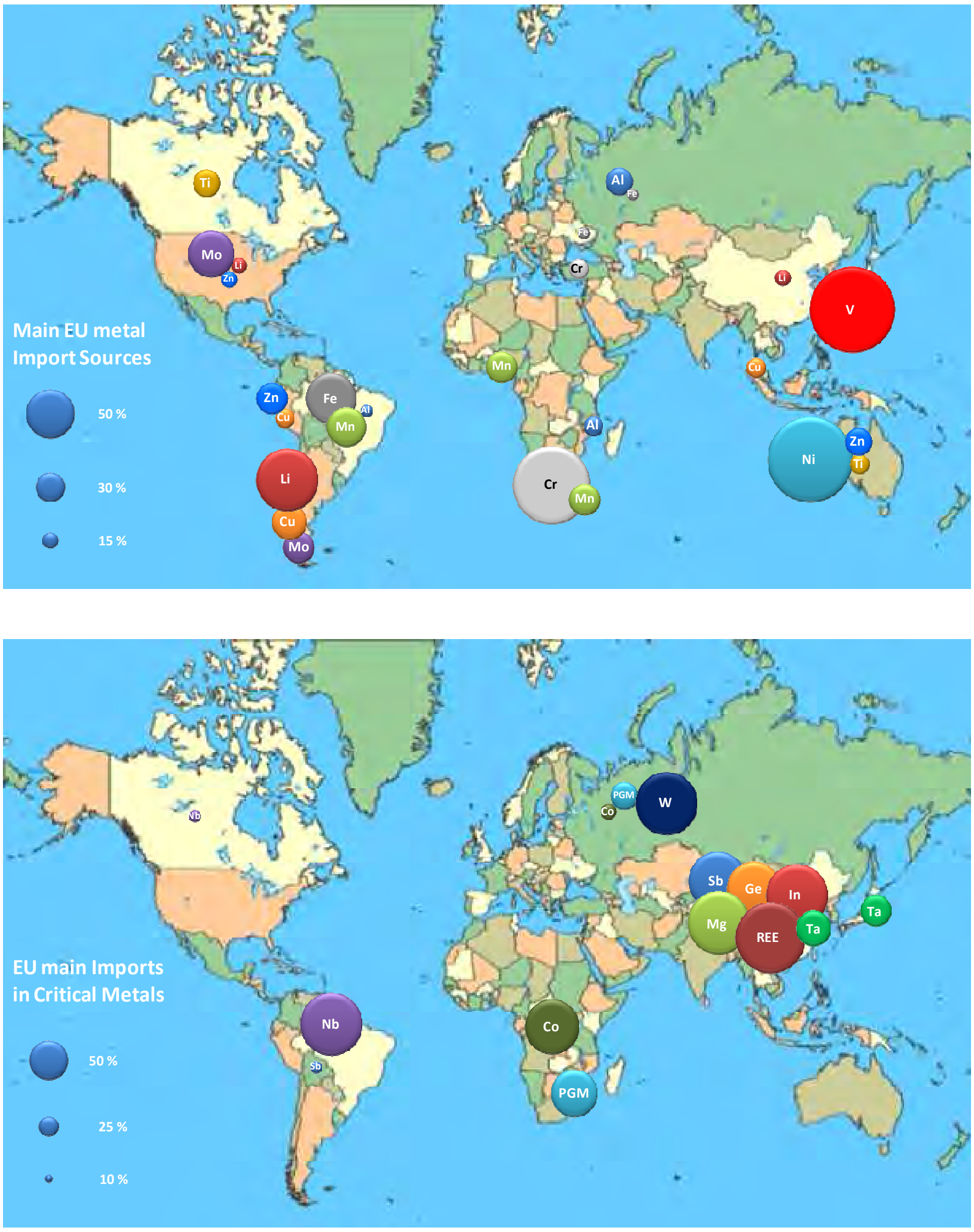

FIGURE III.1. Main EU import sources

The production of many materials is concentrated in a small number of countries, e.g. more than 90% of REE and antimony and more than 75% of germanium and tungsten are produced in China, 90% of niobium is produced in Brazil and 77% of platinum in South-Africa. Supply risks may arise as a result of political-economic instability of the producing countries, export or environmental restrictions taken by these countries. The main producing countries for a number of important metals are presented in the map of figure III.2.

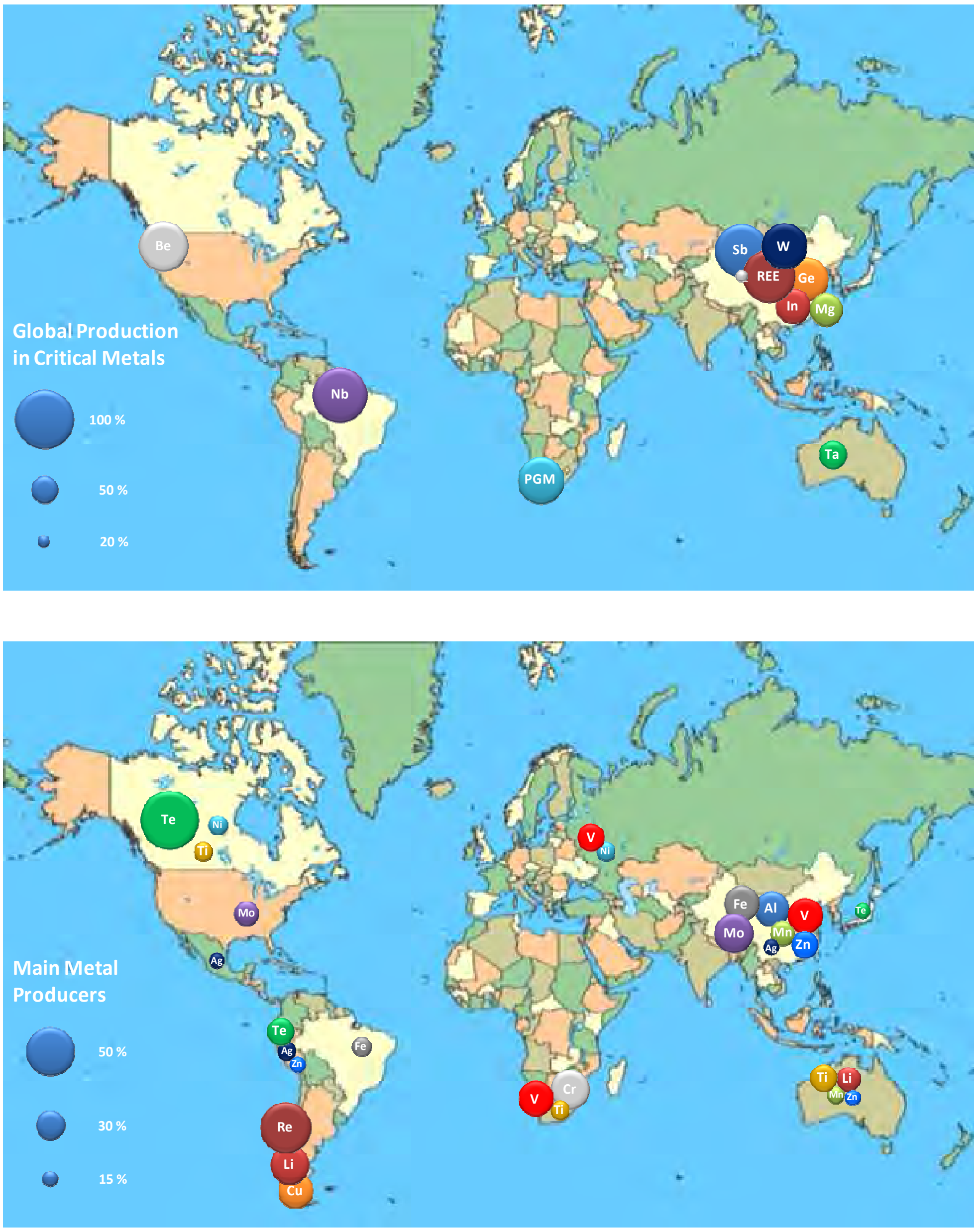

FIGURE III.2. Main producing countries for a number of important metals

Some materials are derived as by-products or coupled products. High tech metals are often by-products of mining and processing major industrial metals, such as copper, zinc and aluminum, which means that their availability is largely determined by the availability of the main product (e.g. gallium is found in bauxite; germanium and indium typically with zinc; tellurium with copper and lead ores; rare earths can be found within iron ore; rhenium is produced as a by-product from molybdenum, which in itself is a by-product of copper). Notable examples of coupled elements are the platinum group metals (PGMs), rare earth elements (REE), and tantalum-niobium, which generally have to be mined and processed together. The co-production and by-production processes create complex relationships between the availability and extraction costs of different materials, which may put their supply into risk. For example, it might not be economic to raise zinc production just to meet an increase in germanium demand.

Due to its low elasticity, mine production cannot adapt quickly to meet structural changes in the demand pattern (e.g. it takes 9 to 25 years to develop a large copper project). This increases the risk of the occurrence of crises, such as the rush for tantalum in 2000 due to the boom of mobile phones.

On the other hand, the EU has valuable raw material deposits (e.g. EU is the largest or second largest producer of certain industrial minerals). However, their exploration and extraction faces increased competition for different land uses and a highly regulated environment, as well as technological limitations in access to mineral deposits. In this frame, significant opportunities exist for securing material supplies by: a. streamlining the land permitting process for mining; b. supporting research on extraction and processing; c. improving resource efficiency and recycling; and d. substitution of certain high-risk raw materials by others that are not facing similar restrictions and supply limitations.

The non-energy raw materials (minerals and metals) that are considered essential for the efficient functioning of the EU economy, together with data on the EU import dependence on them and data related to recycling or substitution, are presented in table III.1.

TABLE III.1. Non-energy raw materials, minerals and metals, essential for EU economy

Raw materials	EU import dependence (%)	Comments
aluminum	6.8	
antimony	100	Low recycling due to the dissipative nature of its major applications; no effective substitute for its major application (flame retardant); China is the major producer (>90%) and has posed export restrictions, therefore there is high supply and price risk
barytes	10.2	No recycling or substitution by other materials
bauxite	75	Bauxite is not recycled; refractory bauxite products up to 50% recycled; bauxite is the most important starting material for aluminum production, though other sources of alumina are technically feasible; refractory bauxite cannot be substituted
bentonite	4.4	Most EU needs are sourced internally as EU (and Turkey) produce ~ 27% of world production; no recycling; substitution dependents on the particular application, as bentonite characteristics cannot be matched by a single alternative mineral or material
beryllium	100	~ 19% recycled from old scrap; substitution is difficult and wherever it is possible there may be a loss of performance
chromium	50	recycling rate in US is ~ 30%; no information available on recycling in Europe; its major applications have no substitute
clays (and kaolin)	23	Recycling can be assumed to be insignificant and substitution very difficult; 10 year ago substitution in paper industry was significant while recently has reduced
cobalt	100	It is mainly associated with Ni (~50%) and Cu (~35%) and only 15% comes from cobalt operations; Africa (DRC) is the dominant source of mining product supply; recycling from alloy and hardmetal scrap ~68%; recycling not possible from dissipative applications (e.g. pigments, paints, glass); limited substitution options due to its unique properties
copper	47	very significant for EU economy; its production increased by 50% in the last 10 years; its consumption in Europe substantially exceeds production, there is a supply threat due to constrains or restrictions from large producers (companies in South America, Asia and Africa); its use sifts currently from developed countries to emerging economies; recycling is ~40% but remains static; substitution is difficult due to its unique qualities
diatomite	17	recycling is extremely difficult;); limited substitution

		options due to its unique properties
feldspar		Europe is relatively self-sufficient; no direct recycling exists; substitution is not economic
fluorspar	70	China is the main producer but has applied export quotas and taxes, as a result new operations in EU are developing; recycling in EU < 1%; substitution possibilities are limited
gallium	no data available	By-product of bauxite and zinc treatment; China is the main producer (75%) and has imposed trade restrictions; recycling only from new scrap, no from old scrap; substitution is limited only to certain applications
germanium	100	By-product of other metal mining (Cu-Pb-Zn sulphides); recycling is ~30%; it is still the most reliable material for high-frequency applications; in most cases substitution is not economical or leads to performance losses
graphite	95	although EU reserves exist; main import source is China; recycling is technically feasible, but not currently practiced
gypsum		EU is nearly independent from imports
indium	100	its production is connected to lead-zinc production; main import source is China (80%) has applied export quotas and taxes; recycling possibilities are limited (< 1% from old scrap); substitution is possible only for some applications
Iron ores		Europe produces only 1.6%, while China 35%; recycling rate in EU 56%, there is potential for increase up to 70%;
lithium	26	most recycling is done in the field of batteries (target set by EU: 45% of batteries to be recycled by 2016; substitution is possible in batteries, ceramics, greases and manufactured glass
magnesite		as it is only used in the calcined form as Magnesia it cannot be recycled; refractory bricks are recycled up to 10%; substitution of magnesia in the steel industry is very low (5%), while in the cement industry is higher (30%)
magnesium	47	Main import source is China (~80%) and has imposed trade restrictions; recycling rate is 33% but can be increased; it can be substituted by aluminum and zinc in casting and silica and chromium in some refractory applications
manganese	Europe has to be considered import dependent; no data available	recycling is limited, 12-25% form old scrap together with iron; no scrap recycling for manganese; it has no satisfactory substitute in its major applications; it is used as a substitute for other commodities, like chromite or vanadium

molybdenum	100	Major import sources are Chile and USA; export quotas and taxes are applied by major producers; amount recycled as part of new and old steel and other scrap may be ~30%; only little effort have been made to substitute it in its major applications
nickel	31	Nickel demand in EU is quite important; recycling rate 56%; its substitution for alloys production is difficult and leads to reduced performance; for some applications (e.g. hot parts of jet engines) there may be currently no suitable alternative
niobium	100	It is found in connection with tantalum; main import source is Brazil (84%); its demand will increase by 6 times until 2030; recycled niobium about 20% of primary production; substitution is possible, it may involve higher costs and/or loss in performance.
platinum group metals (PGMs)	100	Leading world producer is south Africa (90%) and main import source for EU (60%); are always mined together as coupled elements; are expected to play important role in emerging technologies; recycling is quite efficient, although there is no universal technique for their recovery from post-consumer scrap; they can often substitute for each other, but since platinum and palladium mine production is in the same magnitude this does not necessarily help but can shift the problem from one metal to another
rare earths (REE)	100	Although deposits exist in EU; main import source is China (90%) and has applied export quotas and restrictions; recycling is 1%; for most applications substitutes are available but with loss of performance
rhenium	100	by-product of porphyry copper-molybdenum ores processing; main import source is USA; recycling rate 13%; substitutes are continuously evaluated
silver	40	Recycling rate is high (40-90%) due to its value and its ease of recycling; possible substitutes are: aluminum, copper, gold, palladium, platinum, and several refractory metals;. however, silver is considered the metal with the highest electrical and thermal conductivity of all metals, certain looses in performance could arise; main focus of research for substitutes should be placed in its dissipative applications, such as RFID and textiles
tantalum	100	Recycling is limited (<9%); substitution is difficult and wherever it is possible there may be performance loss
tellurium		Recycling is still embryonic (< 10%) but growing steadily; several materials can replace it in most of its uses, but with losses in production efficiency or product characteristics

titanium	25	Main import sources are Canada and Australia; titanium minerals cannot be recycled as they are used in a dissipative manner, however, titanium metal can be recycled; Only few materials can compete with it concerning its strength-to-weight-ratio and its corrosion resistance
tungsten	73	almost every kind of tungsten-containing scrap and waste can be processed for tungsten recovery; recycling in applications as lamp filaments, welding electrodes and chemical uses is low; substitution possibilities are limited due to high cost of alternative materials/technologies, worse performance, and less environmental friendly alternatives
vanadium	100	Main import source is South Korea (90%); recycling rate is low; substitution is possible for steel containing vanadium but not in aerospace titanium alloys
zinc	64	Recycling rate is 75% and increases every year; substitution is limited mainly due to high cost of alternatives

An expert working group activated under the umbrella of the Raw Materials Supply Group and chaired by the EC analysed the above list of minerals and metals in order to identify the most critical ones at EU level. The group came down to a list of 14 raw materials, which were considered to have relative high economic importance and supply risk for the EU. These materials are:

- antimony
- beryllium
- cobalt
- fluorspar
- gallium
- germanium
- graphite
- indium
- magnesium
- niobium
- PGMs
- REE

- Tandalum
- tungsten

Their main characteristics that make them critical for EU are: (a) the import dependence of EU for all of them (generally more than 70%; in most cases 100%); (b) their use is fundamental in emerging technologies; (c) they are produced as by-products of other main metals treatment or coupled elements; (d) their recycling rate is quite low; (e) the substitution options are limited.

From the rest of the raw materials included in table III.1, the following ones were considered as important for the EU economy, as they are also essential to modern industrial activity as well as to the infrastructure and products used in daily-life. These materials are:

- bauxite-aluminum
- chromium,
- copper
- iron ores
- manganese
- molybdenium
- nickel
- vanadium
- zinc

CHAPTER IV

IDENTIFIED RAW MATERIALS WITHIN WP 1

Partners involved in WP 1 represent in a large extension the major European sectors (e.g. mining, metallurgy, recycling) where raw materials are a crucial part of their business and activities. In consequence, the identified raw materials within this WP is a relevant issue taking in mind that:

- listed raw materials show the real interest of some crucial European sectors in the areas of mining, metallurgy, recycling, rare and critical materials, etc.
- raw materials have been classified based on their nature and source.
- the listed raw materials intends to be complete; anyway, it is open to new inputs if relevant.

IV.1. Primary Raw Materials

In the next table IV.1 is listed the identified primary raw materials which are of interest for WP 1 partners. They are classified in several groups:

- Metallic minerals
- Industrial minerals
- Aggregates
- Natural stones
- Other primary sources

Within each group, the main components (having economic or strategic interest) were outlined.

The used acronyms are:

- PM (precious metals)= Au, Ag
- PGM (platinum group metals)= Pt, Pd, Ir, etc
- REE (rare earth elements)= Y, La, Ce, Eu, Gd, Tb, Yb, Nd, Sm, Gd, etc
- SM (special or critical raw materials)= In, Ga, Ge, Cd, Bi, Te, Sb, Se, Be, Nb, Ta, etc

TABLE IV.1. Identified primary raw materials within WP 1

PRIMARY RAW MATERIALS	VALUABLE COMPONENTS	
Metallic minerals		
Base metals sulphides ores/concentrates (single metal)	Main components:	Cu, Zn, Pb, Ni, Co, etc
	By products:	PM, PGM, SM, REE, etc
Polymetallic base metals sulphides ores/concentrates (mixed metals)	Main components:	Cu, Zn, Pb, Ni, Co, etc
	By products:	PM, PGM, SM, REE, etc
Seafloor masive sulphides ores (mixed metals)	Main components:	Cu, Zn, Pb, Ni, Co, etc
	By products:	PM, PGM, SM, etc
Ni-Laterites ores/concentrates	Main components:	Ni, etc
	By products:	Fe, Co, Mn, Mg, PGM, etc
Shallow waters ores	Main components:	Phosphates, Fe, Ti
	By products:	U
Iron ores/concentrates	Main components:	Fe
	By products:	REE, etc
Manganese ores/concentrates	Main components:	Mn
	By products:	
PM ores/concentrates	Main components:	PM
	By products:	
PGM ores/concentrates	Main components:	PGM
	By products:	
REE ores/concentrates	Main components:	REE
	By products:	
SM ores/concentrates	Main components:	SM
	By products:	
Industrial minerals		
Industrial minerals	Industrials:	Alumina, Bauxite, Si, S, graphite, Fe, Mg, Ti, Li, Be, Cr, Zr, W, Ba, etc
	Chemicals:	Phosphates, gypsum, limestone, magnesia, soda ash, fluorspar, salt, zeolite, clays, diatomite, perlite, bentonite, etc
	Construction:	Gypsum, clays, silica, kaolin, etc

	Fillers:	Al, Ti, Si, Mg, soda ash, gypsum, limestone, sodium sulphate, zeolite, clays, diatomite, etc
Aggregates		
Quarried bedrock and mainly aluvial and/or glaciofluvial deposits	Uses: Construction:	Concrete Mortar Roads Asphalt Railways
Natural stones		
Natural stones	Uses: Construction: Other:	Paving Cladding Walling Flooring Roofing Armour stones Gravestones/Tombstones Decoration (ornamental stones)
Other primary sources		
Sea water	Main components: By products:	Cl, Na, Mg, etc

IV.2. Secondary Raw Materials

In the next table IV.2 is listed the identified secondary raw materials of interest for WP 1 partners and are classified as follows:

- Metallic materials
- Ashes, slags, rocks, construction demolition wastes
- Liquids and effluents

Within each group, the main components (having economic or strategic interest) were outlined. The used acronyms are:

- PM (precious metals)= Au, Ag
- PGM (platinum group metals)= Pt, Pd, Ir, etc

- REE (rare earth elements)= Y, La, Ce, Eu, Gd, Tb, Yb, Nd, Sm, Gd, etc
- SM (special or critical raw materials)= In, Ga, Ge, Cd, Bi, Te, Sb, Se, Be, Nb, Ta, etc

TABLE IV.2. Identified secondary raw materials within WP 1

SECONDARY RAW MATERIALS	VALUABLE COMPONENTS	
Metallic materials		
Zinc secondaries: EAF dust, Waelz oxides, zinc oxides, etc	Main components: By products:	Zn Pb, Ag, Fe, etc
Lead secondaries	Main components: By products:	Pb PM, SM, etc
Primary/secondary batteries recycling	Main components: By products:	Zn, Pb, Ni, Co, Li, Mn, Mo, etc SM, etc
Electronic wastes, low-energy electric bulbs	Main components: By products:	Cu, PM, PGM, REE SM, Fe, etc
Industrial residues, wastes	Main components: By products:	Zn, Pb, PM, PGM, SM, etc
Combustion flue dusts and residues	Main components: By products:	Si, Al, Mg, Fe, Se, Zn, Mn, REE, etc
Catalysers from automotive and industries	Main components: By products:	PGM, V Fe
Heaps, tailings, stockpiles, leaching precipitates	Main components: By products:	Base metals, PM, SM, etc
Red mud from aluminium industry	Main components: By products:	Fe, Al, V, Mg, etc
Residues from steel industry: steelmaking slags, dusts, sludges, refractories, old landfills	Main components: By products:	Fe, Ni, Cr, V, Mo…, and substitutes for aggregates Zn, Pb…
Solar panels and components	Main components: By products:	In, Cd, Te, Cu, Fe, etc
Solar panels and components	Main components: By products:	In, Cd, Te, Cu, Fe, etc
Magnets and magnetic	Main components:	REE (Nd)

materials	By products:	
Solid state lighting - Production & End of life wastes	Main components: By products:	SM(Ga, In, Ge), RE (Y, Ce, Eu), PM(Au,Ag),
Ashes, slags, rocks, construction demolition wastes		
Fly ash	Main components:	Cement susbtitute from metals production
Granulated blast furnace slag (GBFS)	Main components:	Cement susbtitute from metals production
Construction demolition products	Main components:	Fe, substitutes for aggregates
Liquids and effluents		
Industrial effluents and bleed solutions	Main components:	Base metals, SM, etc
Acid mine drainage	Main components:	Base metals, etc
Leachate, dump water	Main components:	Base metals, SM, etc
Side streams of oil production	Main components:	V

CHAPTER V

PILOT PLANTS ISSUES

The Raw Material Initiative is likely the result of the following actions carried out within the EU for last years:

- Tackling the challenges in commodity markets and on raw materials.
- The review of the Market Abuse Directive (Directive 2003/6/EC (OJ L 96, 12.4.2003) in trading in commodity markets abuse and transactions where abusive practices can occur are properly covered under pan-EU rules.
- The review of the Markets in Financial Instruments Directive (Directive 2004/39/EC (OJ L 145, 30.4.2004) to improve further the transparency of trades and prices in commodity.
- The Alternative Investment Fund Management Directive (COM(2009) 207, 30.4.2009) for transparency of funds for investors and national supervisors, and impact of these funds on the markets for commodity derivatives.
- Waste Framework Directive for developing 'End-of-Waste' criteria for specific waste streams, and work is advancing on rules for ferrous metals and aluminium, copper, recovered paper and glass.
- Europe 2020 target Action Plan on Resource Efficiency Europe.
- The White book on Renewable Energy Sources (RES).
- The Environmental Technology Action Plan.
- The EU sustainable development strategy.
- The Barcelona 3% RTD intensity objective.
- The EU Lisbon Strategy for Growth and Jobs.
- The Kyoto Protocol and related international agreements.
- The Green paper towards a European strategy for the security of energy supply
- ... and others.

The first Communication on the Raw Materials Initiative was proposed to the European Parliament from the Commission in November 2008[16] highlighting the critical dependence of the EU on certain raw materials and proposing the development of an appropriate and coherent EU policy in this regard.

[16] Communication from the Commission to the European Parliament and the Council: The Raw Materials Initiative – Meeting our critical needs for growth and jobs in Europe {SEC(2008) 2741}.

Based on the first Communication on the Raw Materials Initiative, on 2 February 2011 the European Commission adopted a new strategy document[17] which sets out targeted measures to secure and improve access to raw materials for the EU. And this strategy document reinforces the three pillars approach: (a) fair and sustainable supply of raw materials from international markets; (b) fostering sustainable supply within the EU; (c) boosting resource efficiency and promote recycling. To develop this new strategy on raw materials the Commission is considering launching an Innovation Partnership on Raw Materials in line with the 'Innovation Union' flagship initiative of Europe 2020 strategy.

On January 2011, a workshop was held under the auspices of Sustainable Mineral Resources (SMR) European Technology Platform (ETP) in cooperation with other platforms and organisations such as CONSTRUCTION, EUMAT, ESTEP, MANUFUTURE, SUSCHEM, EUROFER, EUROGEOSURVEYS, etc, and a committee was appointed to coordinate the ETP´s activities and involvement in the Raw Materials Initiative. In this meeting, the guidelines to develop the five Work Packages were established. This WP 1 is devoted to develop new innovative technologies and solutions for sustainable raw materials supply and the main objective is:

- To propose specific issues for demonstrating ten innovative pilot plants for raw materials extraction, processing, and recycling, within the Innovation Partnership on Raw Materials.

V.1. Pilot Plants Issues

The partners involved in this WP 1 have proposed ideas for pilot plants aiming to develop innovative technologies or solutions along the entire value chain, including the next areas:

[17] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions – Tackling the challenges in commodity markets and on raw materials. COM(2011) 25 final.

- Exploration
- Extraction (Mining)
- Processing
- Recycling

  (Some of the preliminary proposals cover more than one of the above areas)

In order to prepare the preliminary ideas for pilot plants of the same bases, a template has been proposed to be filled by the promoters of the pilot plants issues. A copy of such template is included in the Annex 2.

The pilot plants issues proposed by WP1 partners is presented in the table V.1, while pilot plants issues proposed by other associations such as Eurometaux and SusChem are shown in tables V.2 and V.3.

TABLE V.1. Pilot Plants issues proposed by WP 1 partners

PARTNER	PILOT PLANT ISSUE
	EXPLORATION
Par WEIHED LUT SWEDEN	New exploration technologies for defining the European deep mineral resources
	MINING
Julien DENEGRE TECHNIP FRANCE	Deepsea pilot mining system
Horst HEJNY MIRO GERMANY	Fully automated mineral winning process/system including near-to-face processing and backfilling for deep metal mines
Volker WETZIG VSH Hagerbach SWITZERLAND	Underground quarry and processing
	RAW MATERIALS PROCESSING
Patrick D´HUGUES BRGM FRANCE	Bioleaching of polymetallic sulphides (To extract Base metals, Precious metals, and Minor metals including RREE)
Mrs. Susan EHINGER G.E.O.S. GERMANY	Semi-mobile pilot technology for processing of nickel laterites (To Extract Ni and Co)

Carlos FRIAS Tecnicas Reunidas, S.A. SPAIN	Low-grade and polymetallic minerals processing trough innovative hydrometallurgical technologies (To extract Base metals, Precious metals, and Minor metals including RREE)
Urs PEUKER TU-Freiberg GERMANY	Developing and demonstration of processing fine structured ores (Technology innovation in the fields of grinding and flotation for fine ores)
	RECYCLING
Bjorn SCHOUENBORG CBI SWEDEN	Develop innovative technologies for the production and usage of aggregates for concrete and asphalt, based on 100 % manufactured (crushed) hard rock and alternative aggregates, e.g Construction Demolition Waste (CDW) (To reuse alternate and demolition wastes)
Arun JUNAI TNO THE NETHERLANDS	Recycling plant for the Recovery of valuable components from solid state & fluorescent lamps lighting, electronics, and photovoltaic CIGS (To recover In, Ga, RREE, Cu, etc)
Witold KURYLAK IMN POLAND	Metal value recovery from flotation tailings (To recover Zn, Pb, Ag, Cu, etc)
Marcin OLSZEWSKI IMBIGS POLAND	Development of new innovative technologies and solutions for sustainable management of fine-grained waste containing silica (To recover/reuse silica)
Ioannis PASPALIARIS NTUA GREECE	Production of rare metals from exisiting EU mining and metallurgical wastes and electronic scraps (To recover PGM, Sb, Ge, Ga, In, etc)
Bernard VANDERHEYDEN CRM, Liege (ESTEP) BELGIUM	(1) Dedicated smelting reduction technology for the valorization of steelmaking slags and other by-products (To recover Fe, Ni, Cr. Zn..., and produce valuable mineral products, e.g. cement substitutes) (2) Recovery of iron, zinc and other metals from secondary raw materials through a dedicated thermochemical process (To recover Fe, Zn, Ni, Cr, Pb)

TABLE V.2. Pilot Plants issues proposed by EUROMETAUX

PILOT PLANT ISSUE
Establishing a European hydrometallurgy institute
Rare Earth Recycling
Landfill and Urban Mining
Evaluation of the Quantity of Portable Electrical and Electronic Equipment (EEE) stored in the EU Economy (with a special emphasis on Portable Rechargeable Batteries and their critical raw materials content)
IARTT Project: To a more sustainable European 'Recycling Society' through Innovative Aluminium Recycling and Transformation Technologies
NEWGARC Project: Strategic modeling tool for foreseeing aluminium material needs and energy use
ALURE Project: ALUminium REcycling

TABLE V.3. Pilot Plants issues proposed by SUSCHEM

PILOT PLANT ISSUE
Rare Earths Recovery

V.2. Pilot Plants Overview

An overview of the pilot plants issues is listed in the next table V.4.

TABLE V.4. Overview of the proposed Pilot Plants issues

	Subject	Submitted by	Partners	Main Research Needs	Materials	Pilot Plant Size/Capacity	Location	Project Duration	Estimated Budget (million Euros)
A	**Geology**								
1	New Exploration technologies for defining the European deep mineral resources	LTU (Sweden)	LTU (Sweden), Eurogeosurveys individual members (tbc), Boliden (Sweden), Inmet (Sweden), INPL Nancy (other industry and academic partners from ETP-SMR)	3D and 4D models, New visualisation and acquisition tools, New deep penetrating technologies,	Ores and minerals	Not applicable	To be defined	7 years (2013-2020)	128
B	**Mining**								
1	Deep sea pilot mining system	Technip (France)	Technip (France), MMD (UK), Seatools (NL), Feluwa (DE), Institut fur mechanische Aufbereitungstechnik (DE), SGL (DE), German Marine Research Consortium	Deep sea mineral resource exploration, Assessment, Fragmentation or penetration of hard materials, Remote operation floating ships	Seafloor massive sulphides (SMS): Cu, Zn, Pb, PM	1/4 full scale (250,000 t SMS in 6 months time, 1500 t/day	To be defined	3.5 years	55
2	Fully automated mineral winning process/system including near-to-face processing and backfilling for deep metal mines	MIRO (UK)	MIRO (UK), LKAB (Sweden), Boliden (Sweden), Lundin Mining (Sweden), KGHM (Poland), K+S (Germany), Agnico Eagle Finland OY, KSL Kupferschiefer Lausitz GmbH, LUT (Sweden), TU Freiberg, other partners tbc	New tools to break rocks, New sensors for Metals detection and Materials separation for undergrund use, New mining systems for use at great depths, Underground processing and automated backfilling	Metal ores: Cu, Zn, Pb, PM, PGM, Re, Se, Te	100,000 - 500,000 t ores/year	To be defined	8 years (2012-2020)	300
3	Underground quarry and processing	VSH (Switzerland)	VSH AG (CH), Amberg Engineering AG (CH), Kappeli AG (CH), Institut fur mechanische Aufbereitungstechnik	New blasting technologies, New processing units for narrow undergorund spaces, Storing of sand and gravel in underground quarries.	Sand and gravel	60,000 m^3/year processed materials	In Switzerland	3.5 years	To be defined
C	**Raw Materials Processing**								
1	Bioleaching of polymetallic sulfides	BRGM (France)	BRGM (France), Mintek (South Africa), Boliden (Sweden), Tecnicas Reunidas (Spain), RTB Bor (Serbia), IMM Bor (Serbia), University of Belgrade (Serbia)	Innovative application of moderate thermophilic bioleaching process for polymetallic minerals, Demonstrate the integration of downstream hydrometallurgy processes for the recovery of valuable metals.	Cu, Zn, Pb, Ni, Co, PM	1-5 t concentrates/ores per day	To be defined	3.0 years	17
2	Semi-mobile pilot technology for processing of nickel laterites	GEOS (DE)	GEOS (DE), TU Berkgakademie Freiberg (DE), BRGM (France), IGME (Greece), KGHM (Poland), University of Bangor (UK), Deutsche Rohstoff AG (DE), Nickelhutte Aue-(DE)	Mining, sorting, extraction, and processing of small deposit Nickel laterites using semi mobile pilot plants	Ni	10 t ores/day	To be defined	4.0	10
3	Low grade and polymetallic minerals processing through innovative hydrometallurgical technologies	Tecnicas Reunidas (Spain)	Tecnicas Reunidas, S.A. (Spain), Boliden (Sweden), IMN(Poland), IMNR (Romania), KGHM (Poland), ZGH Boleslaw (Poland)	Obtaining polymetallic concentrates from low grade ores at lower cost and higher metals recovery, Innovative hydrometallurgical technologies to process the polymetallic concentrates aiming to extract more metals utilising the developed clean technologies	Cu, Zn, Pb, PM, In, Ga, REE	1-2 t base metals (Cu+Zn+Pb) production per day	To be defined	3.5	20-30
4	Developing and demonstration of processing fine structured ores	TUBAF (DE)	TUBAF (DE), GEOS (DE), University of Oulu (Finland), Full industrial partners	New developments in Wet-Grinding, Mechanical activation, Specific Reagents, Aids, and Nano-flotation for fine particles, 1-5 microns	Metallic ores	2-20 kg/h final concentrate	To be defined	4.0	6.3
5	Establishing a European hydrometallurgy institute	ERAMET (France)	To be defined	An Institute with the required capacity of scale to conduct continuous testing of hydrometallurgical processes devised under laboratory conditions and to guarantee their viable development.	Polymetal raw materials, Recycling	To be defined	To be defined	A few years	50-100
D	**Recycling**								
1	Development of innovative technologies for the production and usage of aggregates for concrete and asphalt, based on 100% manufactured (crushed) hard rock and alternative aggregates, eg Construction Demolition waste (CDW)	CBI (Sweden)	CBI (Sweden), SINTEF (Norway), 2-3 aggregate producers, 1-2 manufacturerers of machinery (eg. Sandvik, Metso), Concrete and asphalt producers, Geological surveys and other invited partners	Development of innovative technologies for aggregates processing, characterization, mix proportioning from excavated bedrock from infrastructural works e.g. demotion wastes for the usage in concrete and asphalt	Aggregates for concrete and asphalt	100,000 t aggregates/year	To be defined	2 years (2012-2014)	1.5
2	Recycling Pilot Plant for the recovery of valuable materials (Ga, In and REE) from photovoltaics(CIGS), solid state and fluorescent lighting and electronics	TNO (NL)	TNO (NL), Philips (NL), Aixtron (DE), van Gansewinkel(NL), Technicas Reunidas (Spain), BRGM (France)	Development of recycling system to recover Ga, In & REE: (design, identification, separation, dissolution and purification)	Ga, In, REE	3 t per year recycled scarce material	To be defined	5 years	15
3	Metal value recovery from flotation tailings	IMN (Poland)	IMN (Poland), ZGH Boleslaw (Poland), and other potential partners to be discussed	Mobile pilot installations to recover base metals from flotation tailings using new to be developed processes (grinding, treatment and recovering)	Cu, Zn, Pb	1,000 t flotation tailings/day	In Poland	4 years	20
4	Development of new innovative technologies and solutions for sustainable management of fine grained waste containing silica	IMBIGS (Poland)	IMBIGS (Poland), and others to be agreed	Development of new methods to treat wastes containing fine-grained silica for re-use	Silica	0.5-10 t mineral wastes/hour	To be defined	3 years	2-5
5	Production of Rare Metals (PGM, Sb, Ge, Ga, In) from existing EU mining and metallurgical wastes and e-scrap	NTUA (Greece)	NTUA (Greece) and others to be agreed	Development of innovative small sized Electric Arc Furnaces and Pyrometallurgical processing of waste or primary materials	Zn, Pb, PGM, Sb, Ga, Ge, In, REE	1MW AMRT Electric Arc Furnace with a working capacity of 850 litres	To be defined	4 years	8-10
6	Dedicated smelting reduction technology for the valorisation of steel melting slags and other by-products	ESTEP (Brussels)	Steel makers (carbon & Stainless) and associated R&D Centres, Partners from relevant sectors like cement industry, coal industry, coal based power plants, car dismantling/shredding, urban incinerators, plant builders	Development of smelting reduction technology for the valorisation of Steel slag, dusts, and sludges	Fe, Ni, Cr, V, Mo, Zn... and susbstitutes for aggregates	50,000 t slags/year	To be defined	4 years	30
7	Recovery of Iron, Zinc and other metals from secondary raw materials through a dedicated thermochemical process	ESTEP (Brussels)	Steel makers (carbon & Stainless) and associated R&D Centres, Partners from relevant sectors like non ferrous metallurgy, car dismantling/shredding, urban incinerators, plant builders	Preparation methods for steel plant by-products (pelletising, briquetting, extrusion), and rotary Hearth Furnace or alternative carbothermic reduction technology	Fe, Zn, Ni, Cr, Pb	1-2 t by-products/hour	To be defined	4 years	30
8	Rare earth recycling	Umicore (Belgium)	Umicore (Belgium), collection, physical separation, REE-refining, academia	Production of REE-rich concentrate with a minimal non ferrous contamination, Refining into individual REE components	End of life products and materials bearing REE	5,000-10,000 t raw material/year	To be defined	5 years (2015-2020)	A few million Euros to a few tens of million Euros
9	Landfill and urban mining	Umicore (Belgium)	Umicore (Belgium), collection, energy valorization, academia, landfill owners	To develop a multi-purpose low-value waste treatment flow sheet capable of processing a wide variety of feed material from dumps, landfills and urban waste streams containing high-calorific value fractions and metal-containing streams of low value	Landfilled materials containing metals such as Co, Ni, Cu, PGM, Se, Te, In	100,000 t raw material/year	To be defined	5 to 10 years	10 million Euros for a limited project to over 100 million Euros if it covers the whole value chain
10	Evaluation of the quantity of portable electrical and electronic equipment (EEE) stored in the EU economy	RECHARGE	RECHARGE (The European Association for Advanced Rechargeable Battery Technologies)	EU study of the home storage (Urban Mining) of portable EEE appliances, with a specific objective to identify those that are powered by Portable Rechargeable Battery appliances	Electrical and electronic wastes containing Co, Li, REE	To be defined after study accomplishment	To be defined	1.5 years	0.65
11	To a more sustainable European 'Recycling Society' through innovative aluminium recycling and transformation technologies	EAA (Belgium)	EAA and others	Statistics, collection schemes, sorting techniques, melting and purification technologies as well as semi-production processes to turn Europe into a real functioning aluminium recycling society	Aluminium	To be defined for each work package	To be defined	3-5 years	21 million for five work packages
12	Strategic modelling tool for foreseeing aluminium material needs and energy use	Hydro Aluminium	Hydro Aluminium, International Aluminium Institute, NTNU Trondheimorder	In order to be able to predict with some accuracy the future energy uses, and aluminium contribution to the Green House Gases reductions, complex modelling needs to be developed, taking more variables into account than existing aluminium models	Aluminium	Not applicable	To be defined	4 years	4
13	Aluminium Recycling	Hydro Aluminium	Hydro Aluminium, Aleris, Alcan EP, SAPA, Assam Aluminium, TiTech, Sintef, Aachen University	To realize the full material and energy saving potential of post-consumed Aluminium, also for Aluminium scrap currently not collected or of mixed and low quality and exported out of Europe, an improved recycling concept is necessary	Aluminium	To be defined	To be defined	4 years	7

CHAPTER VI

CONCLUSIONS

VI.1. Conclusions

The partners and stakeholders that have collaborated in this Work Package 1 likely represent the most important companies and institutions within the EU in the field of mining and metallurgical raw materials, including recycling. Therefore, this Experts Report is a very valuable document and we (all WP 1 involved partners) hope that it should be considered as a relevant document of reference for further activities within the Raw Materials Initiative, especially in the definition and choice of the “ten demonstration pilot plants”.

Thus, main aim of this report is providing a list of Pilot Plants issue to the European Commission within the European Innovation Partnership on Raw Materials.

The next conclusions can be highlighted as a result of the relevant scientific and technical information compiled and presented in this report:

- The relevant European primary and secondary raw materials of interest have been identified, including major components and other minor elements.

- Suitable technologies and solutions are proposed by WP 1 partners along the entire value chain, including:

  - Geology: 1 pilot plant issue
  - Mining: 3 pilot plants issues
  - Processing (primaries): 5 pilot plants issues
  - Recycling (secondaries): 13 pilot plants issues

  (Some preliminary proposal is covering more than one of above areas)

- Proposed pilot plants issues cover all base metals, including: aluminium, iron, copper, zinc, lead, nickel, chromium, etc.

- Proposed pilot plants issues cover a majority of rare and minor metals such as: indium, gallium, germanium, precious metals, platinum group metals, rare earths, antimony, etc.

- Proposed pilot plants issues also cover other minerals: aggregates, substitutes for aggregates, sand and gravel from underground, silica-based materials, etc.

The authors and contributors of this report are open and would be keen to cooperate with EU Directorates and Officers to facilitate further discussion and additional information in regards to the pilot plant issues included in this Experts Report. For instance, some relevant subjects to be clarified are:

- Selection and prioritisation of the targets and the pilot plants to be finally implemented.
- To define the most convenient number, location(s), and type(s) of pilot plants to be built in accordance with the general politic, social, and economic interest of the EU and their country members.
- How some proposed pilot plants can be properly integrated and combined to produce a more suitable and valuable pilot plant issue.
- How some pilot plants can be interconnected: (i) a certain by-product obtained in a pilot plant may be fed and processed in other pilot facility; (ii) potential and advantageous integration of primary and secondary (recycled) materials to feed a certain pilot plant, etc.
- To identify and propose research topics linked to the diverse pilot plants issues that could be convenient to be included in next calls of NMP and other programmes as a preliminary work to be covered previously to final pilot plan project implementation.
- To identify potential topics for pilot plants that may be crucial or having relevant interest for EU and were not raised in this report.

VI.2. Final Remarks

Both the State of the Art part of this WP1 report and the enclosed list and description of the proposed pilot installations explicitly show how important for Europe is to invest in security of supply of raw materials and in more efficient extraction and recycling in a continuously and rapidly developing Modern Society. The idea of the European Innovation Partnership on Raw Materials seems to perfectly answer that necessity while its suggested scope, from exploration through mining, processing, recovering and recycling provides possibilities for complex addressing of the problem and covering the whole value chain. The WP1 partners involved in this activity clearly support the settlement and growing of EIP-Raw Materials Initiative aiming at producing finally the “ten demonstration pilot plants”.

This report clearly presents significance not only of the recently defined list of critical metals, but also other raw materials having strategic value for the European economy. In consequence, WP1 involved partners proposes that pilot plants actions be focused on all crucial raw materials for Europe, covering base metals and precious metals, rare metals, and critical metals.

The proposed pilot plants list is very broad and covers solutions and installations of various sizes, scope and budgets. This wide variety confirms the high value of the Initiative on the one hand, and on the other, it presents the scope of the research needed in that field. The list does not include all the potentially relevant installations however it indicates, in our view, the main directions to be pursued. In all the cases, however, the development of new technologies should take a holistic approach and focus on interdisciplinary solutions. For the adequate selection and prioritization of the targets it is necessary to establish a representative steering or advisory committee which can support European Commission in making the decisions.

It seems only logical that one of the key roles in the implementation of the Initiative should be played by European Technology Platform on Sustainable Mineral Resources. The ETP SMR has already established good cooperation both within the mineral industry and its research centres and also with other relevant European Technology Platforms. Well coordinated cooperation between the Platforms will form a strong basis for the competent determination of the most valuable and promising research targets and areas of their implementations.

It seems also very important to wider the recognition of the Initiative and raise the awareness of all relevant stakeholders. The idea of the Initiative has already met with broad interest, however for the fruitful and complete implementation of the Initiative it would be most advantageous if all relevant industries, with special consideration for SMEs, were fully aware of its potential.

The EIP on Raw Materials represents a great opportunity for the European economy and will bring benefits not only in the raw materials industry but also in many other directly or indirectly linked to them sectors. Launching of the Initiative will have a fundamental meaning in reaching the objectives of Europe 2020 and in providing European leadership both in technology development and its implementation for securing the raw material supply on our continent.

WP 1

ANNEX 1

WP 1 INVOLVED PARTNERS

A1.1. Contributors to this Experts Report

The partners that made specific contributions to elaborate this report are as follows.

TABLE A1.1. Contributors to the report

INDEX / CHAPTER		CONTRIBUTOR
1	Introduction. Objectives. Stakeholders	Göran BÄCKBLOM, LKAB
2	State of the art: – Lack of suitable technologies – Insufficient recycling – Loss of raw materials in the value chain – Challenging innovative technologies and solutions	Horst HEJNY, MIRO Andrzej CHMIELARZ, IMN Dominique MORIN, BRGM
3	Raw materials and critical materials (European dimension)	Ioannis PASPALIARIS and Maria TAXIARCHOU, NTUA
4	Identified raw materials within WP1 (primaries and secondaries)	Carlos FRIAS, TR
5	Pilot plants issues: Definition, structure, templates Pilot plants overview	Ángel López-BUENDIA, AIDICO Carlos FRIAS, TR Arun JUNAI, TNO
6	Conclusions	Carlos FRIAS, TR
	General co-ordination	Virgilio GARCÍA, TR

A1.2. Partners Involved in WP 1 Activities

The partners involved in WP 1 activities include enterprises, industries, universities, associations, European platforms, etc, and are listed below. This report collects and summarises the work performed by all WP 1partners.

TABLE A1.2. WP 1 Partners list

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ANNEX 2

PILOT PLANTS TEMPLATE

A2.1. Pilot Plants Template

The proposed template for pilot plants description is shown below.

WP 1 *Innovative Partnership-Raw Materials Initiative*

Work package number 1	Developing new innovative technologies and solutions for sustainable raw materials supply
Pilot Plant Issue:	
Partners:	
Project Duration:	
Estimated Budget:	

Introduction. State of the Art

- [What societal problem do you address?]
- [What is the current situation?]

Objectives

- [Targeted materials]
- [Type of activities: exploration, mining, recycling]
- [Objectives should be quantified and measurable]

Innovative Technologies / Solutions

-Technological base:	[Existing technologies necessary for pilot plant] [What needs to be developed?] [Which are the technological challenges?]
-Non-Technological base:	[Is the market environment ready to take up your solutions?] [Are there any barriers (regulatory, standardisation) which hinder full exploitation?]

Expected Impacts (for Europe)

- [Technical, economic, environmental, social]
- [Quantify the expected impacts for Europe. Justify your calculations]
- [How do you plan to exploit and disseminate the solution in Europe?]

Pilot Plant Size/Capacity

-
-

Schedule

-
-

Budget

-
-

(NOTE: Any required research work for pilot plant definition, design, flowsheeting, etc, prior to pilot plant installation and operation will be performed within the pilot plant work plan).

WP 1

ANNEX 3

PILOT PLANTS PRELIMINARY PROPOSALS

A3.1. Pilot Plants Issues

Following are listed the pilot plants preliminary proposals and ideas as received by the promoters.

EUROPEAN TECHNOLOGY PLATFORM
ON SUSTAINABLE MINERAL RESOURCES

Annex B: Comments to the WP1 Draft Experts Report

Comments to the WP1 Experts Report

- The tables justifying the elements targets for recycling is fine: FIGURE II.2. The periodic table of global average end-of-life functional recycling, could be done for Mining?
- also the coverage of the WP1 scheme on FIGURE II.1. The entire value chain for raw materials is interesting.
- However, it could be made shorter and more synthetic

Pilot plants:
- some of the the pilot plants are very interesting, but overall they are not very equal in terms of R&D ambitions, size and scope, and unfortunately there is no overview "map" (raw materials, countries), so it is difficult to see what Europe really needs vs. what ETPs can offer and what/who is missing.
- please could you think of something which could represent the pilot plants map? i tried to group your potential pilots and other needs, and made a little table/map (below) to see what we have at the moment;
- for the moment i see no specific pilot in the area of industrial minerals, but i guess it could be something similar to construction minerals
- the same for extraction from sea water, but from Public consultation we see the interest and i believe that it can be an opportunity for Europe

		Metals	Industrial Minerals	Construction minerals
Exploration of raw materials		- Exploration technologies for defining the European deep mineral resources		
Primary raw materials mining	Continental	- Deep mining	- Underground Quarrying???	- Underground Quarrying
	Marine	- Extraction from sea water - Deep sea mining	-	-
Raw materials processing		- Pre-concentration technology	-	-
Secondary raw materials reuse and recycling		- High tech metals - Basic metals	- Waste?	- Construction waste
Substitution		- High tech elements (GA, In, REE) - Catalysts		

There is another relevant initiative for a PPP on "Sustainable Process Industry" where ETP SMR is also involved.
- please, check the common links and possible overlaps

- the form of the document is quite good, they highlighted important points, you could do that in your document.

Compared with this SPI proposal your report is quite long and I think it is better to shorten: Can you try to focus it better.
