Critical raw materials for the EU

Report of the Ad-hoc Working Group on defining critical raw materials

The *ad-hoc* Working Group is a sub-group of the Raw Materials Supply Group and is chaired by the European Commission

Note: The full report will be available on the Enterprise and Industry Directorate General website http://ec.europa.eu/enterprise/policies/raw-materials/documents/index_en.htm

European Commission
Enterprise and Industry

This report is the result of work carried out under the chairmanship of the Commission services with the participation of a working group of experts and the technical support of external consultants. It does not necessarily represent the opinion of the European Commission.

This report is subject to an open consultation up to 15 September. It is available on the web site of the DG Enterprise and Industry where further details are provided.

Based on extensive background research, important input to this document has been provided by Fraunhofer ISI, under contract to the European Commission (contract N° - CE-0279977/00-34), as well as by Bio Intelligence (contract N°- ENV.G.4/FRA/2008/0112).

TABLE OF CONTENTS

Executive summary

Although raw materials are essential for the EU economy, their availability is increasingly under pressure. Within the framework of the EU Raw Materials Initiative, it was decided to identify a list of critical raw materials at EU level, in close cooperation with Member States and stakeholders. The attached report presents the outcome of this cooperation achieved through an expert working group ("the Group") which was active between April 2009 and June 2010 under the umbrella of the Raw Materials Supply Group.

With regards to geological availability, the Group observes that, as geological scarcity is not considered as an issue for determining criticality of raw materials within the considered time horizon of the study, e.g. ten years, global reserve figures are not reliable indicators of long term availability.

Of greater relevant are changes in the geopolitical-economic framework that impact on the supply and demand of raw materials. These changes relate to the growing demand for raw materials, which in turn is driven by the growth of developing economies and new emerging technologies. Moreover, many emerging economies are pursuing industrial development strategies by means of trade, taxation and investment instruments aimed at reserving their resource base for their exclusive use. This trend has become apparent through an increasing number of government measures such as export taxes, quotas, subsidies etc. In some cases, the situation is further compounded by a high level of concentration of the production in a few countries.

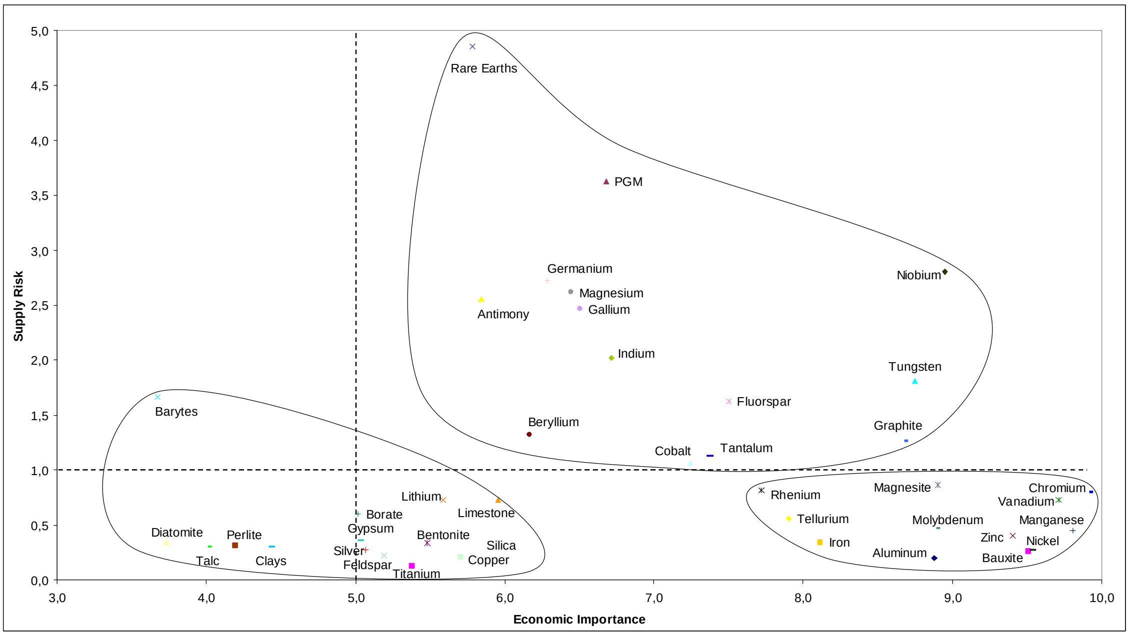
This report analyses a selection of 41 minerals and metals. In line with other studies, the report puts forward a relative concept of criticality. This means that raw material is labelled “critical” when the risks of supply shortage and their impacts on the economy are higher compared with most of the other raw materials. Two types of risks are considered: a) the "supply risk" taking into account the political-economic stability of the producing countries, the level of concentration of production, the potential for substitution and the recycling rate; and b) the "environmental country risk" assessing the risks that measures might be taken by countries with weak environmental performance in order to protect the environment and, in doing so, endanger the supply of raw materials to the EU. Building on existing approaches, this report sets out an innovative and pragmatic approach to determining criticality.

In particular,

- It takes into account the substitutability between materials, i.e. the potential for substitution of a restricted raw material by another that does not face similar restrictions.
- It deals with primary and secondary raw materials, the latter being considered as similar to an indigenous European resource.
- It introduces a logical way to aggregate indicators and makes use of widely-recognised indexes.

- o It presents a transparent methodology.

Based on a criticality methodology, calculations are made regarding the economic importance and supply risk of the 41 materials.



The Group considers that those 14 raw materials falling within the top right cluster of the above diagram are critical. As noted, this is due to their high relative economic importance and to high relative supply risk. The 'environmental country risk' metric does not change this list of critical materials.

List of critical raw materials at EU level (in alphabetical order):

Antimony	Indium
Beryllium	Magnesium
Cobalt	Niobium
Fluorspar	PGMs (Platinum Group Metals)[1]
Gallium	Rare earths[2]
Germanium	Tantalum
Graphite	Tungsten

[1] The Platinum Group Metals (PGMs) regroups platinum, palladium, iridium, rhodium, ruthenium and osmium.
[2] Rare earths include yttrium, scandium, and the so-called lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium)

For the critical raw materials, their high supply risk is mainly due to the fact that a high share of the worldwide production comes from China (antimony, fluorspar, gallium, germanium, graphite, indium, magnesium, rare earths, tungsten), Russia (PGM), the Democratic Republic of Congo (cobalt, tantalum) and Brazil (niobium and tantalum). This production concentration, in many cases, is compounded by low substitutability and low recycling rates.

Concerning the materials positioned in the sub-cluster in the lower right corner, it has to be stressed that a small shift in one of the parameters of the supply risk metric may result in a sudden change upwards. In order words, a slight change in the underlying variables may result in one of these materials being reclassified as 'critical'. For several of the materials positioned in the sub-cluster in the lower left corner, notably the industrial minerals, the group considers that possible supply risks may occur within a longer time horizon should 'competition to land' continue to adversely affect production from quarries or mines in the EU.

One of the most powerful forces influencing the economic importance of raw materials in the future is technological change. In many cases, their rapid diffusion can drastically increase the demand for certain raw materials. Based on a study commissioned by the German Federal Ministry of Economics and Technology, the demand from driving emerging technologies is expected to evolve sometimes very rapidly by 2030.

Global demand of the emerging technologies analysed for raw materials in 2006 and 2030 related to today’s total world production of the specific raw material (Updated by BGR April 2010).

Raw material	Production 2006 (t)	Demand from emerging technologies 2006 (t)	Demand from emerging technologies 2030 (t)	Indicator[1] 2006	Indicator[1] 2030
Gallium	152	28	603	0,18	3,97
Indium	581	234	1.911	0,40	3,29
Germanium	100	28	220	0,28	2,20
Neodymium (rare earth)	16.800	4.000	27.900	0,23	1,66
Platinum (PGM)	255	very small	345	0	1,35
Tantalum	1.384	551	1.410	0,40	1,02
Silver	19.051	5.342	15.823	0,28	0,83
Cobalt	62.279	12.820	26.860	0,21	0,43
Palladium (PGM)	267	23	77	0,09	0,29
Titanium	7.211.000 [2]	15.397	58.148	0,08	0,29
Copper	15.093.000	1.410.000	3.696.070	0,09	0,24

[1] The indicator measures the share of the demand resulting from driving emerging technologies in total today's demand of each raw material in 2006 and 2030;
[2] Ore concentrate

The main driving emerging technologies for the critical raw materials are the following:

Raw material	Emerging technologies (selected)
Antimony	ATO, micro capacitors
Cobalt	Lithium-ion batteries, synthetic fuels
Gallium	Thin layer photovoltaics, IC, WLED
Germanium	Fibre optic cable, IR optical technologies
Indium	Displays, thin layer photovoltaics
Platinum (PGM)	Fuel cells, catalysts
Palladium (PGM)	Catalysts, seawater desalination
Niobium	Micro capacitors, ferroalloys
Neodymium (rare earth)	Permanent magnets, laser technology
Tantalum	Micro capacitors, medical technology

Recommendations

The recommendations are of two types: recommendations for follow-up and further support, and policy-oriented recommendations to secure access to and material efficiency of critical raw materials. The Group refrains from specifying detailed actions, but instead indicates areas where measures should be undertaken.

The Group recommends that the list of EU critical raw materials should be updated every 5 years and that the scope of the criticality assessment should be increased.

The Group recommends that steps be taken to:

- *improve the availability of reliable, consistent statistical information in relation to raw materials;*
- *promote the dissemination of this information, notably by preparing a European Raw Materials Yearbook with the involvement of national geological surveys and mining/processing industries. It should focus on improving the knowledge on the availability of resources and on their flow into products through the value-added chains of the EU economies;*
- *establish indicators of competition to land in the Member States;*
- *encourage more research into life-cycle assessments for raw materials and their products on a "cradle-to-grave" basis;*
- *create a working group(s) to further analyse the impact of emerging technologies on demand of raw materials.*

The Group recommends that a sub-group of the Raw Material Supply Group of the European Commission should be set up to ensure follow-up of this report on critical raw materials.

The Group recommends policy actions to improve access to primary resources aiming at:

- *supporting the findings and recommendations resulting from the work carried out by the ad hoc working group on "Best practices in the area of land use planning and permitting" with a view to securing better access to land, fair treatment of extraction with other competing land uses and to developing a more streamlined permitting processes;*

- *promoting exploration, and ensuring that exploration by companies is regarded as research activity;*
- *promoting research on mineral processing, extraction from old mine dumps, mineral extraction from deep deposits, and mineral exploration in general, notably under EU RTD Framework Programmes;*
- *promoting good governance, capacity-building and transparency in relation to the extractive industries in developing countries, notably in the area of critical raw materials;*
- *promoting sustainable exploration and extraction within and outside of the EU.*

The Group recommends that the following policy actions, with regard to trade and investment as defined in the trade raw materials strategy, be pursued:

- *maintain current EU policy choices in the negotiation of bilateral and regional trade agreements;*
- *consider the merits of pursuing dispute settlement initiatives at WTO level so as to include in such initiatives more raw materials important for the EU industry; such actions may give rise to important case law so long as existing GATT rules lack clarity and are limited in scope;*
- *engage without reservation in consultations with third countries whose policies are causing distortions on international raw materials markets in order to discourage certain policy measures and to request adherence with market forces;*
- *foster an effective exchange-of-views on certain policies made within the institutional framework of EU economic cooperation agreements (e.g. with China on the latter country's NFM recycling plan to year 2015);*
- *continue to raise awareness on the economic impact of export restrictions on developing and developed countries in various multilateral fora, such as WTO or the OECD;*
- *consider shaping a new EU-wide policy on foreign investment agreements in such a manner as to better protect EU investments in raw materials abroad and ensure a level playing-field with other foreign investors who benefit from the backing of State funds;*
- *continue to increase coherence of EU policy with respect to raw materials supply, for example in the assessment of injurious dumping and subsidies.*

The Group 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 products with critical raw materials for proper collection instead of stockpiling them in households (hibernating) or discarding them into landfill or incineration;*
- *improving overall organisation, 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.*

The Group recommends that substitution should be encouraged, notably by promoting research on substitutes for critical raw materials in different applications and to increase opportunities under EU RTD Framework Programmes.

The Group recommends that the overall material efficiency of critical raw materials should be achieved by the combination of two fundamental measures:

- *by minimising the raw material used to obtain a specific product function; this covers every step from smart production with metals and minerals savings to substitution of potentially critical raw materials by less critical ones;*

- *by minimising raw material losses into residues from where they cannot be economically-recovered.*

The measures should be evaluated with regard to impacts on environmental and economic performance over the entire value chain.

1. INTRODUCTION

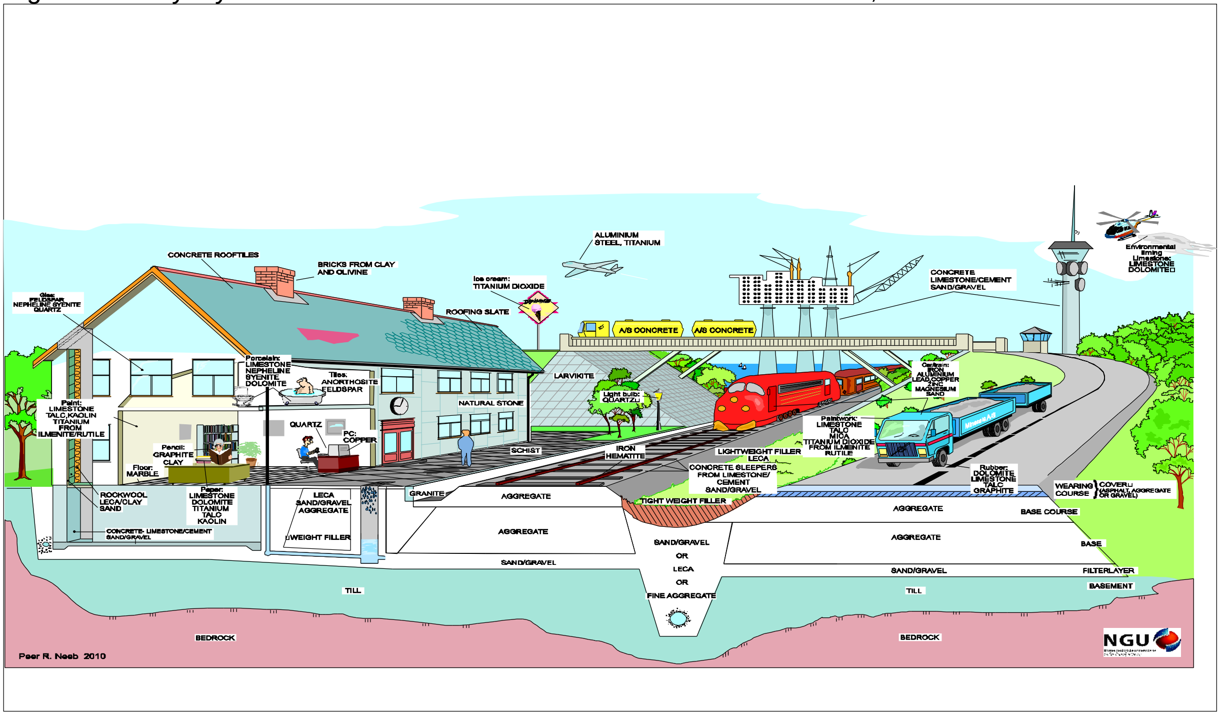
Raw materials are essential for the efficient functioning of Europe's economy. However, whereas the importance of oil and gas has often been highlighted, the essential role of non-energy materials such as minerals and metals has not received equal attention.

Yet industrial minerals are indispensable for a wide range of downstream industries. Most people are usually not aware that feldspar is used in the production of television and computer screens, car headlamps, and soda bottles; silica is used in products such as tableware, ornaments and wall and floor tiles; while speciality talc can be used to improve the performance of biological wastewater treatment plants.

Metals are also essential to modern industrial activity as well as to the infrastructure and products used in daily-life. For instance, copper and aluminium are used in cables that transport electrical power over great distances to the most remote locations, and zinc protects the steel infrastructure that supports them under all weather conditions. Moreover, high tech metals are indispensable ingredients for the development of technologically sophisticated products. Modern cars, flat-screen televisions, mobile phones and countless other products rely on a range of materials, such as antimony, cobalt, lithium, tantalum, tungsten and molybdenum. The same group of high-tech metals are also fundamental to new environmentally friendly products, with electric cars requiring lithium and neodymium, car catalysts platinum, solar panels requiring indium, gallium, selenium and tellurium, energy efficient high-speed trains requiring cobalt and samarium, and new fuel-efficient aircraft rhenium alloys.

All these minerals and metals are present everywhere in the fabric of society today

Figure 1: Everyday's uses of minerals and metals. Source: Peer R. Neeb, 2006.



Securing reliable and undistorted access to non-energy raw materials has become a critical challenge to many resource-dependent countries all over the world. Industrialised regions like the EU, US and Japan, have explicitly recognised the challenges which the availability of certain raw materials may pose for the functioning of their economies. Their assessments help their governments to take appropriate steps in mitigating supply restrictions and specific actions such as stockpiling.

Europe is in a particularly vulnerable position.

On the one hand, Europe is highly dependent on imports for many raw materials which are increasingly affected by growing demand pressure from emerging economies and by an increasing number of national policy measures that disrupt the normal operation of global markets. Moreover, the production of many materials is concentrated in a small number of countries, e.g. more than 90% of rare earths and antimony, and more than 75% of germanium and tungsten are produced in China, or 90% of niobium in Brazil and 77% of platinum in South-Africa. In addition, high tech metals are often by-products of mining and processing major industrial metals, such as copper, zinc and aluminium, which means that their availability is largely determined by the availability of the main product. Besides, due to its low elasticity (e.g. it takes 9 to 25 years to develop a large copper project), mine production cannot adapt quickly to meet structural changes in the demand pattern. 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, while the EU still has valuable deposits and much under-explored and unexplored geological potential, their exploration and extraction faces increased competition for different land uses and is required to take place in a highly regulated environment. It is for example not unusual in the EU for 8 to 10 years to elapse between the discovery of deposits and the start of actual production. Member States are increasingly aware of these challenges for instance Sweden has modernised its mining legislation and introduced lead times in the permitting process. At the same time, a significant opportunity exists for securing material supplies by improving material efficiency and recycling.

In order to address these complex and interrelated challenges, the European Commission has launched an integrated strategy in November 2008: the EU Raw Materials Initiative. It encompasses measures in three areas to secure sustainable access from outside Europe, improving framework conditions for extracting minerals within Europe, and promoting the recycling and resource efficiency of such materials.

One priority action of the Initiative is to identify a common list of critical non-energy raw materials at EU level, in close cooperation with Member States and stakeholders. Some Member States[3] have already carried out assessments with the aim of determining how critical some materials are to their economy, but up until now there has been no comprehensive study at the European level.

---

[3] Some references are included in annex 8 of Commission Staff Working Document SEC (2008) 2741 of 4 November 2008.

In order to facilitate this process, an ad hoc group, hereafter called the Group, was created under the umbrella of the Raw Materials Supply Group[4] in April 2009. The Group consisted of a mix of experts from national ministries, geological surveys, extractive and downstream industries, and other stakeholders (see annex IV for list of names). The Group was tasked with assisting the Commission in defining critical raw materials at EU level.

The objective of the work was to develop a methodology to assess criticality and then apply this methodology to a selection of raw materials. The work was facilitated by technical input by the Fraunhofer ISI and Bio Intelligence. This report describes the methodological approach that was developed, as well as the results of applying this approach to selected raw materials. It concludes with a series of recommendations.

As such, this Report provides an important stakeholder input in preparation for the Communication that the Commission will deliver to the Council on the implementation of the Raw Materials Initiative by the end of 2010.

[4] The Raw Materials Supply Group is an expert group with a long standing history. It is chaired by Enterprise and Industry DG, and comprises representatives from Member States, industry and other stakeholders.

2. ASSESSING CRITICALITY

2.1 Geological and technical availability

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

2.1.1 Key terms and definitions

In order to support sound policy and investment decisions, forecasts of mineral availability must be based on clear, unambiguous and, wherever possible, standardised terminology. The most important key terms are defined below:

A *mineral deposit* is any accumulation of a mineral or a group of minerals that may be economically valuable. The value of a deposit depends on how much mineral there is available, what it costs to mine and process, either locally or internationally, its current and future market price, and the political and social framework to access such deposits.

Mineral deposits occur only at those locations where geological processes have concentrated specific minerals in sufficient quantities to be potentially mined. Consequently, unlike most other forms of development such as homes, commercial areas, farmland, roads and other infrastructure, the possible sites for a mine or quarry are tied to a particular location and restricted to a few, relatively small areas.

The key concepts of reserves and resources are often confused and used inconsistently, with little or no appreciation of the important differences between them:

- a '*mineral reserve'* is the part of the resource which has been fully geologically evaluated and is commercially and legally mineable. Reserves may be regarded as 'working inventories', which are continually revised in the light of various 'modifying factors' related to mining, metallurgy, economics, marketing, law, the environment, communities, government, etc.
- the '*reserve base*[5]' includes the 'mineral reserve' plus those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. It has been a widely utilised concept. However publication of reserve base estimates was discontinued in 2010[6].

---

[5] In addition, the term '*resource base'* has been used in literature - this is the total amount of the mineral commodity contained in the earth's crust.
[6] USGS Mineral Commodity Summaries 2010

- a '*mineral resource*' regroups all identified resources. It is a natural concentration of minerals or a body of rock that is, or may become, of potential economic interest as a basis for the extraction of a mineral commodity. A resource has physical and/or chemical properties that makes it suitable for specific uses and it is present in sufficient quantity to be of intrinsic economic interest. It encompasses 'mineral reserve' and 'reserve base' plus other identified resources which could be exploited in the future if required according to the economic situation.

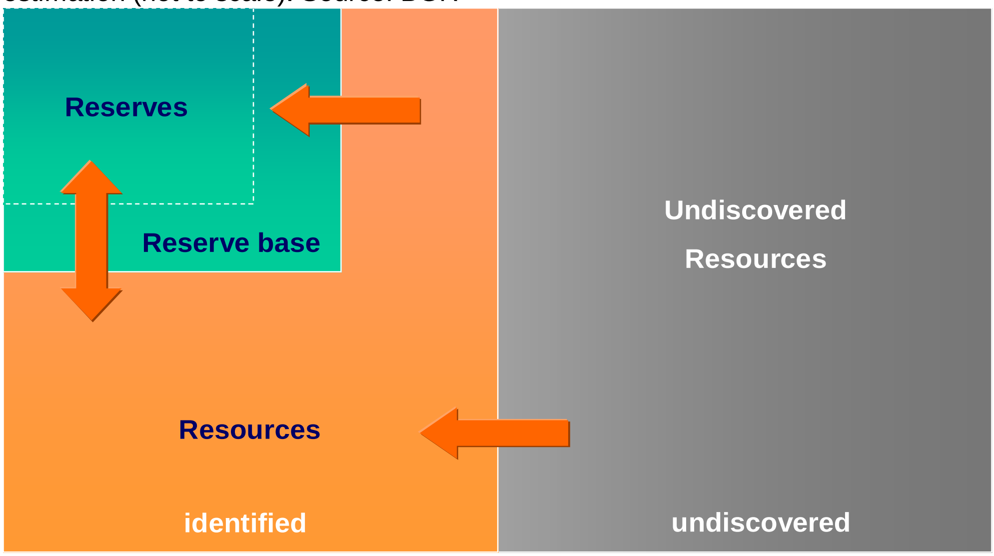
For the purpose of this study, the concept of mineral reserve is the most relevant. It is mineral reserves rather than resources that are actually mined.

However, it is important to note that identified resources do not represent all mineral resources available on earth. Some resources are undiscovered. They comprise[7]:

- '*hypothetical resources*', which are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geological conditions;
- or '*speculative resources*', which may occur either in known types of deposits in favourable geological settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential.

As illustrated schematically in figure 2 the undiscovered resources and identified resources, including reserve and reserve base, represent very different quantities of a mineral with associated major differences in the likelihood of their economic extraction[8].

Figure 2 Schematic illustration of the relative size of key terms used in resource and reserve estimation (not to scale). Source: BGR



[7] USGS Mineral Commodity Summaries 2010

[8] It should be noted that more complex resource/reserve classification schemes, including heavily qualified and detailed definitions, are used in various codes for the corporate reporting of reserves in major mining countries. Adherence to a code of this type, such as the JORC Code in Australia and the SME Code in the US, ensures full and transparent disclosure of all material facts and is obligatory for stock market listing in the host country.

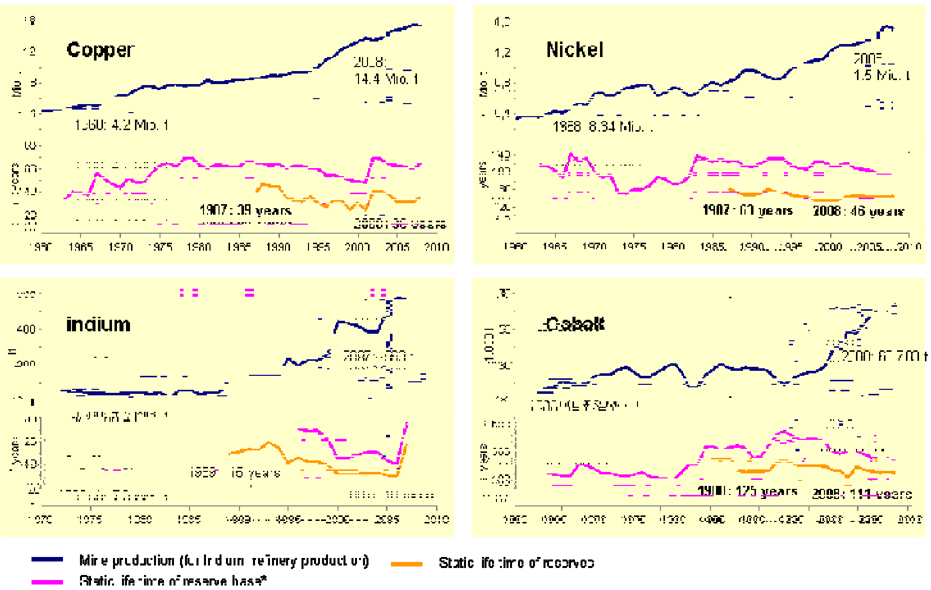
2.1.2 Geological availability

Given the scale of global demand for mineral raw materials it is important to consider whether adequate resources of minerals and metals are present in the Earth's crust and technically available to meet our future needs. Increased recycling, improved material efficiency and demand management will play important roles, but for the foreseeable future it is likely that new stocks of 'virgin' raw materials within and outside the EU will continue to be required.

The uncertainties associated with resource estimates are very large. Nevertheless over the past the reserves have been constantly replenished from undiscovered and identified resources. As a consequence, over the past 50 years, the extractive industries sector has succeeded in meeting global demand and the calculated life time of reserves and resources has continually been extended further into the future (figure 3). This is the result of normal economic behaviour. Mining companies normally only invest what they require for their short-term needs to prove reserves and thus to justify commercial investment decisions over a period of, say, 20 years. They don't necessarily aim at proving the full ore body. There is no indication that the extractive industry would fail to continue to maintain this record.

It can thus be concluded that published reserve figures do not reflect the total amount of mineral potentially available and compilation of global reserve figures are not reliable indicators of long-term availability. Estimates of 'reserves', 'reserve base' and 'resources' , and the static life time of mineral raw materials calculated from them, should not be used in the assessment of future mineral availability as they are highly likely to give rise to erroneous conclusions. The Group considered that geological scarcity is not an issue for determining the criticality of raw materials in the time horizon considered in this study.

Figure 3: Calculated static life time of mineral reserves and the reserve base for copper, nickel, cobalt and indium (y = years; t = tonnes). Source: BGR. Data for reserves and the reserve base are from the USGS.



By-products and coupled production of metals

Some metals face specific supply challenges since they are derived as “by-products” or “coupled products”, mostly from ores of major or “carrier” metals in which they are present in low concentrations (Figure 4). Typical by-product metals are germanium, gallium, selenium, tellurium and indium, which are normally extracted in addition to the carrier metal. For example, gallium is found in bauxite (aluminium ores), germanium and indium typically with zinc, and tellurium with copper and lead ores; rare earths can be found within iron ore. Rhenium is special as it is produced as a by-product from molybdenum, which in itself is a by-product of copper. The economic driver for mining here is clearly the major metal. However, by-product metals can generate additional revenue, if they can be extracted economically; in some cases, however, they are regarded as impurities that drive up production costs.

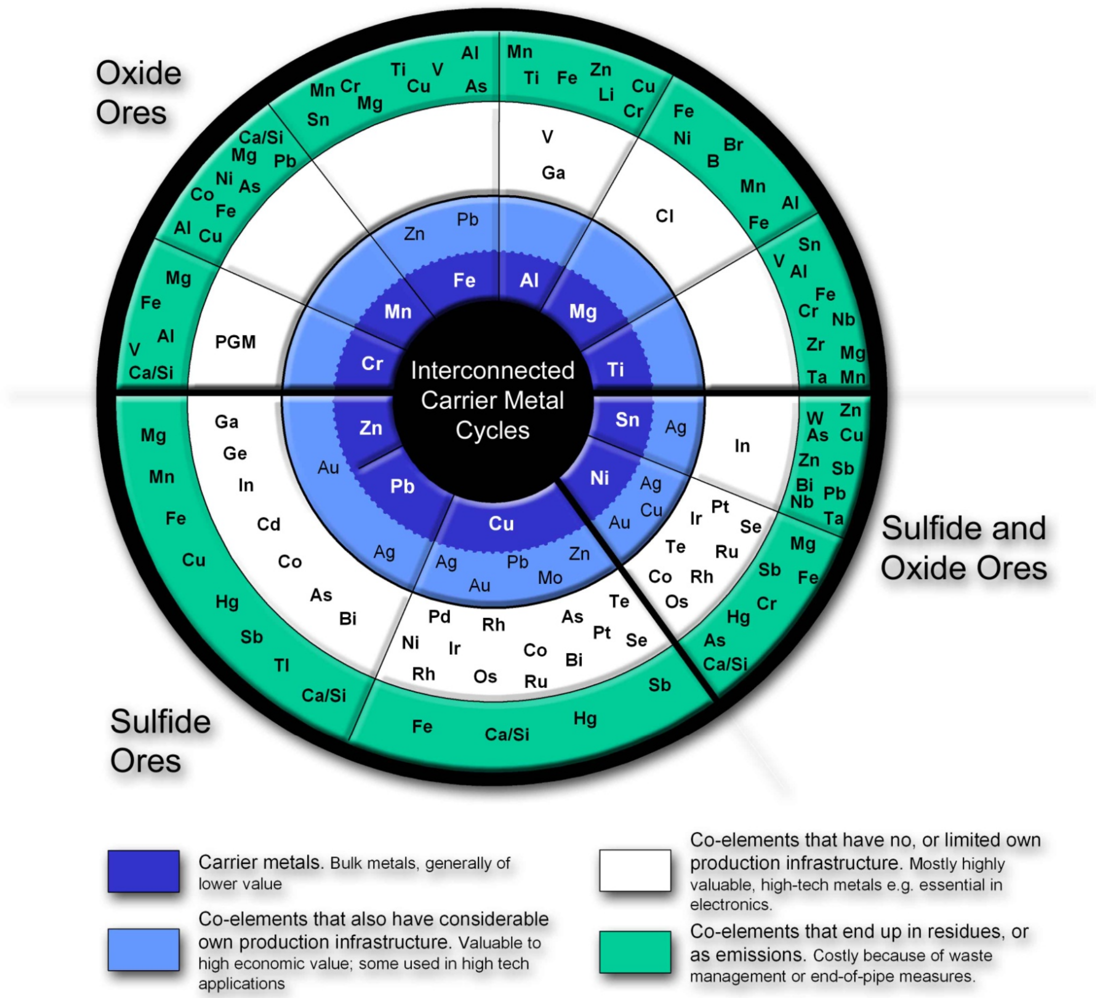
In some deposits groups of minor metals may occur as “coupled elements” without a real carrier metal. Notable examples include the platinum group metals (PGMs), rare earth elements (REE), and tantalum-niobium which generally have to be mined and processed together. However, some metals normally produced as by-products may also be mined as target metals on their own if they occur in elevated concentrations (e.g. cobalt, bismuth, molybdenum, gold, silver, PGMs and tantalum).

Supply of by-products or coupled products could be at risk if the volume mined does not meet a change in market demand. For example, it would not be economic to raise zinc production just to meet an increase in germanium demand. Therefore, metals normally produced as by-products or coupled products have highly complex demand/supply, technology and investments requirements, and price patterns which need to be considered in future market analyses[9].

As with by-products and coupled production of metals, industrial minerals face specific supply challenges as some are produced and traded as specialities. For example, barite and limestone of high grade and whiteness are highly specialised fillers for the paint and paper industry, special bentonites are used for foundry sands as absorbers or as rheology modifiers in the form of organoclays or in the production of nanocomposite polymer materials, acid grade fluorspar has to meet a certain grade and purity criteria, and wollastonite of acicular type (silica sand) has special applications in plastics, rubber or in pigments. Today, each of these materials is high tech products. Customers not only need a reliable source, but also a continuing high and equal quality of the products with some deposits reaching their limitations. The supplier base for such products is in many cases highly concentrated.

[9] Hagelüken and Meskers, 2010

Figure 4. The metal wheel (after Reuter et al. (2005) and Verhoef et al. (2004), with permission of A.M. Reuter)



2.1.3 Technological development

The key driver that has enabled supply to keep up with demand in the past, has actually been the technological progress in exploring, mining and processing mineral raw materials.

Current reserves represent only a small portion of the mineral resources remaining in the earth's crust. Additional reserves are continually identified at existing mines and known deposits, and through the discovery of previously unknown deposits. Such deposits may occur in frontier areas, such as the seafloor, deserts, extreme depth, the arctic region or even in terrains previously regarded as unprospective. Completely new deposit styles may be recognised thus opening up new exploration potential in such terrains. For example, the class of deposits known as epithermal precious and base metal deposits, which were unknown before the 1970s, now contributes to global precious metal reserves.

Even the discovery of a single new deposit may have a major impact on global reserves and production of a number of commodities. For example, the Bayan Obo deposit accounts for the majority of China's 31 % share of the world's rare earths reserves.

It is also significant to note that in most parts of the world exploration drilling seldom exceeds 200 m in depth, although it may extend to 500 m in established mining districts. Also most mineral deposits worked at present are close to the surface, with the deepest open-pit mine less than a kilometre deep and the deepest underground mine about 4 km deep. Given that the continental crust averages about 35 km in thickness it is clear that there is enormous potential for the discovery of buried mineral deposits. New developments in exploration and mining technology and their application in new terrains and at greater depths are therefore critical for ensuring the technical availability of mineral raw materials.

In addition to new discoveries, technological advances throughout the remainder of the mineral commodity life cycle (processing, manufacturing, recycling and substitution) also have important roles to play. More efficient processing methods enabling improved yields on by-products in particular can have a highly significant impact on future availability of certain metals such as gallium or germanium. Also, more efficient use of resources and recycling can be very effective in supplementing existing reserves. However, mining will continue to be the main basis of supply in the future because of the structural growth of usages, growth of population and global demand. Consequently (BRGM) is most important to strengthen the geological knowledge base to locate new deposits as well as frame conditions for efficient recycling and global political and economic framework under which the extractive sector operates, and thus to ensure it performs effectively and in a sustainable manner.

2.1.4 Geopolitical-economic availability

On the basis of the above-mentioned arguments, there seem to be no grounds to justify some of the alarmist forecasts published in recent years that suggest supplies of some raw materials will soon be wholly depleted.

Rather than a static view of geological availability, it is proposed to adhere to a more dynamic model. Such a dynamic model should not only take into consideration the general trends in reserves and technological developments. It should also consider changes in the geopolitical-economic framework that impact on supply and demand of raw materials.

From the beginning of the century, there has been an unprecedented surge in demand, mainly driven by the strong and continuous growth of emerging economies. While the effects of the financial crisis in 2008 led to a temporary slow down of growth, it is expected to resume more quickly in the emerging countries which will therefore maintain high pressure on raw materials demand. This situation is in some cases compounded by a high level of concentration at the level of producing countries, as highlighted in section 1.

Moreover, many emerging economies are pursuing industrial strategies by means of trade, taxation and investment policies aimed at reserving their resource base for their exclusive use. This has become increasingly apparent during the past decade with the mushrooming of a variety of government measures. Some of these measures are at odds with commitments taken by these countries under international trade agreements, such as WTO commitments. Export taxes, quotas, subsidies, price-fixing or restrictive investment rules are distorting international trade and investment in an increasing number of raw materials markets. An indication of specific export restrictions is highlighted in the individual profiles for the raw materials assessed in this study. These are selected from a Commission inventory of export restrictions applied on raw materials by third countries, which was started in 2007 and is updated on a yearly basis[10].

Case study: the WTO case against Chinese export restrictions

China applies export restrictions – including quotas and export duties – on a series of key raw materials. Because of the especially strong position of China as a supplier of these materials, the imposed restrictions not only increase global prices for these materials but they also distort worldwide competition for the downstream industries. Indeed, industries processing these materials in China have access to cheaper inputs than their competitors abroad, including EU industries, which amounts to an artificial subsidisation of the domestic industry. This distorts the level playing field that can be legitimately expected among WTO members.

The EU has raised its concern about these restrictions with China over the years in all the various bilateral forums available, be they technical or high level. Unfortunately, these efforts have not been met by any engagement or even reaction from the side of China. In reaction to this the EU, together with Mexico and the U.S., requested formal WTO consultations on 23 June 2009. Since these discussions did not lead to an amicable solution, a request was made on 21 December 2009 for the establishment of a dispute settlement panel at the WTO.

This panel request focuses on a batch of products including yellow phosphorous, bauxite, coke, fluorspar, magnesium, manganese, silicon metal, silicon carbide and zinc.

The measures in place – quotas, export duties and minimum export prices – appear to be in violation not only of general WTO rules, but also of specific commitments that China signed up to, as part of its WTO Accession Protocol. This sets out either prohibitions of recourse to export taxes or establishes strict caps on a limited number of products, all of which have been broken. Export quotas without justification are prohibited under Article XI of GATT. China has similarly failed to notify many of its export quotas to the WTO, despite its firm commitment to do so.

Although the geological availability of most mineral resources is potentially high the impact on the environment, energy demand and costs of exploiting lower grade ores, mining from greater depths and in geographically more challenging locations must not be overlooked. Providing long term access to the available mineral resources therefore requires more focus on sustainable mining, both on research for environmentally sound mining and processing technology, as well as on the social and economic aspects of

[10] In its current version the export restrictions database covers 19 countries including Algeria, Argentina, Brazil, China, Egypt, India, Indonesia, Kazakhstan, Russia, South Africa, Thailand and Ukraine. It is important to note that it represents the Commission's knowledge of the situation as of November 2009 and does not offer any guarantee of completeness. Moreover, this inventory is purely factual and does not presume of the legitimacy nor of the legality (particularly WTO-wise) of any of the referenced measures.

mining. To counteract the steady increase in global demand for primary mineral resources and to reduce the negative societal impacts associated with meeting this demand, it is necessary to recycle materials more widely and more effectively, to increase material efficiency in manufacturing processes and to search for new substitute raw materials through technological innovations.

2.2 Scope

2.2.1 Geographical coverage

This is the first time that the criticality of raw materials has been analysed at the European Union level. However, in recent years different criticality assessments have been carried out at the level of Member States, such as Austria, France, Germany and the UK, which are referred to in annex 8 of the Communication on the Raw Materials Initiative.

These different criticality assessments use varying criteria and adopt varying time perspectives. The data sources and means of aggregating information to determine criticality also vary. As a result, the different methodologies have delivered different outcomes in relation to the criticality of particular non-energy raw materials. The diverse outcomes will also arise from national differences in the importance of manufacturing industries reliant on specific materials, on the technologies in place which affect substitutability and on national recycling rates. Hence, it is very likely that the identification of critical raw materials may differ according to the geographical coverage. An example of this relates to sand and gravel and crushed rock ("aggregates"). The EU is largely self-sufficient in aggregates. However, the availability of aggregates from regional and local sources is essential for economic development, in view of logistical constraints and transports. This could lead to the situation whereby the supply of aggregates could be identified as critical to the economy of a specific region or country in the EU, but not necessarily at the overall European level.

Case study: aggregates

Europe currently needs some 3 billion tonnes of aggregates (crushed stone, sand and gravel) a year, equivalent to over 6 tonnes per capita. Aggregates are an essential ingredient of the key building components that make up the residential, social and commercial infrastructure of modern European society. Some 90% overall of these aggregates come from naturally-occurring deposits, the remaining 10% coming from recycled materials, marine and manufactured aggregates.

The production of recycled and marine aggregates will continue to grow. However in the longerterm some 85% of demand will still need to come from aggregates. As aggregates are heavy and bulky, it is imperative for economic and environmental reasons (transport, fuel consumption, carbon dioxide generation, noise, road damage, etc) that these are sourced local to the main markets. Therefore access to local aggregate resources is a key issue both for the aggregates industry and for European society.

While there is general availability of indigenous aggregates at European and national levels, economically viable regional and local access is often severely constrained. Therefore, unless there is the acceptance Europe-wide of a strategy to provide viable local provision, the necessary future supply of aggregates at a local level will become even more acute, and this will quickly spread to the regional and subsequently to the national level.

2.2.2 Materials covered

In line with the assessments made by Member States and other countries, it was decided to focus on non-energy minerals and metals. For the purpose of simplification, in this report the term “metals” is used to indicate “metallic ore”; definitions are highlighted in a box below.

Definitions

Metallic ore: mineral, from which a metal can be extracted economically.
Industrial mineral": mineral, which may be used in an industrial process directly due to its chemical/physical properties. Industrial minerals are used in a range of industrial applications including the manufacture of steel, chemicals, glass, fertilisers and fillers in pharmaceuticals and cosmetics, ceramics, plastics, paint, paper, and the treatment of gases and waste, etc. Industrial minerals include barites, bentonite, borates, clays, diatomite, feldspar, fluorspar, gypsum, limestone, silica sand, talc, and many others.

The list of materials to be analysed was ultimately decided by the Group on the basis of their expert advice. Starting with the 20 materials identified in the preliminary assessment made in the Annex 8 of the Communication on the Raw Materials Initiative, 19 materials have been added. For some materials, it was considered appropriate to make a breakdown of their value-chains in order to analyse their specific supply risks. This was the case for bauxite/aluminium and magnesite/magnesium. Consequently a total of 41 materials have been identified as “potential candidates” for criticality and assessed in this study. It is important to stress that the current analysis that covers 41 materials is not exhaustive. If additional materials had been considered it is possible that some of these might also have been regarded as critical.

Table 1: list of materials selected for criticality assessment

Aluminium	Lithium
Antimony	Magnesite
Barytes	Magnesium
Bauxite	Manganese
Bentonite	Molybdenum
Beryllium	Nickel
Borates	Niobium
Chromium	Perlite
Clays (and kaolin)	Platinum Group Metals[11]
Cobalt	Rare earths[12]
Copper	Rhenium
Diatomite	Silica sand
Feldspar	Silver
Fluorspar	Talc
Gallium	Tantalum
Germanium	Tellurium
Graphite	Titanium
Gypsum	Tungsten
Indium	Vanadium
Iron ore	Zinc
Limestone (high grade)	

[11] PGMs include platinum, palladium, iridium, rhodium, ruthenium and osmium
[12] Rare earths include yttrium, scandium, and the so-called lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium)

2.2.3 Time horizon

This study does not focus on very short term supply risks, because that would give rise to unrealistic expectations regarding the possibility for policy makers to intervene. On the other hand it was considered appropriate to adopt a long term perspective which would introduce a high degree of uncertainty. Therefore it was decided that the analysis would look into the supply risks that may arise within a time period of 10 years. It is thus on this basis that – depending on data availability – the future demand and supply of the raw materials was taken into account.

Whatever the methodology used, it was acknowledged that a criticality assessment would only capture the degree of criticality of a raw material at a specific point in time. Accordingly the assessment should not be regarded as fixed, rather the situation should be regularly monitored and the list of materials updated.

2.2.4 Strategic vs critical raw materials

In different studies and policies the term “strategic” is often used instead of “critical” raw materials. The definitions used reveal that materials for military uses are called “strategic”, while those materials for which a threat to supply from abroad could involve harm to the national economy are considered “critical”. It is not within the scope of this study to consider or assess the “strategic” importance of specific raw materials to specific military applications. Consequently the term "critical" will be used in this report.

2.3 A pragmatic approach

Existing studies all determine criticality on the basis of the evaluation of both risk and impacts. In line with this approach, this study has also put forward a relative concept of criticality: a raw material is labelled "critical" when the risks of supply shortage and their impacts on the economy are higher than for most of the other raw materials. Similarly this study has based its assessment on a series of indicators used to evaluate some risks and the potential impact on the economy of potential supply bottlenecks or decreased availability of the raw materials.

Determining criticality and choosing the appropriate indicators is not a matter of exact science and is subject to various methodological challenges. Central questions relate to data availability and how the different indicators should be aggregated and combined.

Building on the various existing methods, this study sets out an innovative and pragmatic approach to determining criticality:

- It considers *three main aggregated indicators* or dimensions, i.e. the economic importance of the considered raw material, its supply risk (for instance restrictive measures from resource-rich countries) and an environmental country risk assessing the potential for environmental measures that may restrain access to deposits or the supply of raw materials. These three aggregated indicators are calculated for each raw material.

- It takes into account the *substitutability* between raw materials, i.e. the potential for substitution of a restricted raw material by another one that is not faced with similar restrictions. In case of easy substitutability, the supply risk is adjusted downward.
- It deals with both primary and *secondary raw materials*, the latter being considered as similar to an indigenous European resource. It symmetrically addresses risks on imports and risks on access to European deposits.
- It introduces a *logical* way to aggregate indicators. For instance the economic importance is calculated by adding the value–added of user sectors weighted by their relative share in the overall use of the raw material. This contrasts with some other studies where the different values of indicators are apparently simply added up without any underlying rationale.
- It makes use of widely *recognised* indexes. For instance it applies a Herfindahl-Hirschman index to aggregate risks in order to take into account the concentration of risks[13]. The supply risk is indeed all the more important when the countries represent a higher share of worldwide production or exportation.
- It presents a *transparent* methodology. The applied methodology allows direct assessment of the relative contribution of the different factors to criticality thus facilitating the justification for policy recommendations.

2.3.1 Economic importance

The importance for the economy of a raw material is measured by breaking down its main uses and attributing to each of them the value added of the economic sector that has this raw material as input.

The breakdown of the economy in sectors is based on the concept of 'value-added chains'. As each step of the value-added chain builds on previous steps, an upstream bottleneck in supply of raw material will threaten the whole value chain. For that reason, the study has introduced the concept of "megasectors" to approximate value-added chains. In this approach the usual NACE codes have been regrouped or broken down with a view to describing value-added chains. This regrouping is certainly more appropriate than the usual NACE codes sectoral breakdown (see Annex II). However where the statistical breakdown based on the value-added chain is not available, the work done by the group can only be approximate. Further statistical information and analysis are required to better assess the concept of the value-added chain.

2.3.2 Supply risks

In order to assess the supply risks, production of the raw materials was considered. The *level of concentration of worldwide production*[14] of the raw material was evaluated by making use of the so-called Herfindahl-Hirschman Index (HHI). This index is widely applied in competition and anti-trust proceedings or assessments. Increases in the HHI index indicate a decrease in competition and an increase of market power, whereas decreases indicate the opposite. In the current study, increases in the HHI index indicate a higher supply risk which will be all the more difficult to overcome if the risky countries are responsible for a large part of worldwide production.

---

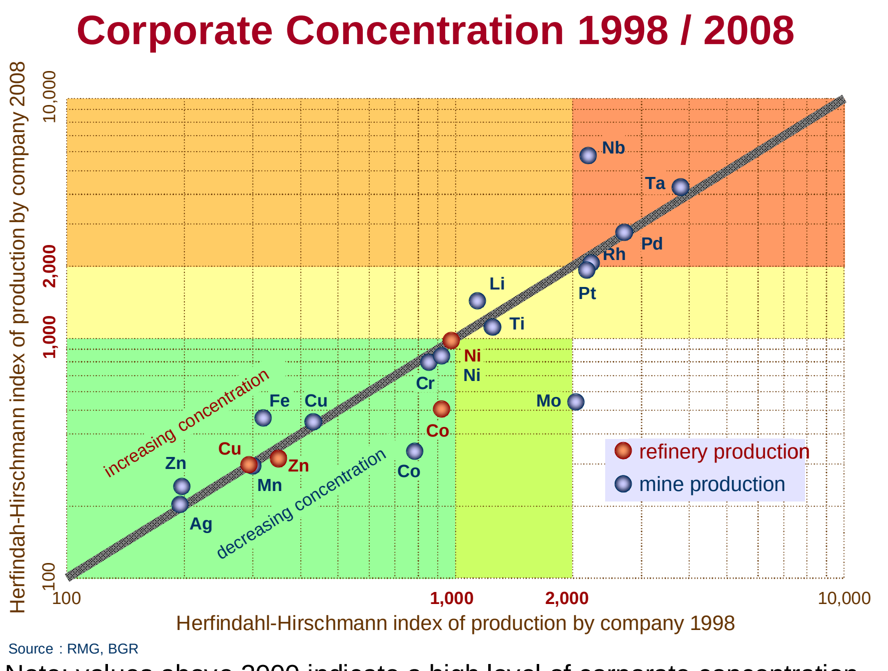
[13] Herfindahl-Hirschman index is normally used to measure the level of concentration of companies.
[14] Production data were based on World Mining Data 2010. Bmwfj, Austria. L. Weber, G. Zsak, C. Reich, M.Schatz.

The HHI-results were subsequently linked to the *political and economic stability of the producing countries*. The political and economic stability of producing countries was measured by making use of the World Bank "Worldwide Governance Indicator". This widely recognised indicator measures six broad components of governance: voice and accountability; political stability and absence of violence/terrorism; government effectiveness; regulatory quality; rule of law; and control of corruption. The Worldwide Governance Indicators[15] report on governance indicators for countries all over the world.

Case study: company concentration

Supply risks may also result from company concentration. For example, the corporate concentration of mine production for niobium, tantalum, and PGMs is high (see figure 5), which means that only few companies control the global market. This also refers to rare earth elements, where Chinese companies act like national corporations (not shown in the figure 5). The level of corporate concentration for niobium has even increased in 2008 compared to 1998. For other materials such as iron, zinc, silver, or copper, the corporate concentration of mine production is low and even decreased for cobalt. Thus, with regard to competition, the supplier base for these materials can be classified as diversified. However, iron is a special case as over 70 % of the iron ore trade is controlled by three companies only. Corporate concentration for traded iron ore is thus much higher. For industrial minerals, many specialities such as high quality filler or refractory products are also provided by only a few companies. The information base about corporate concentration for the studied materials is rather limited and secondly the company concentration potentially shows advantages and disadvantages from the perspective of raw material access (for instance financial solidity versus market power). For these reasons, it was decided not to include indicators of company concentration in the assessment of criticality.

Figure 5. Corporate concentration for selected metal ores and refined products in 1998 and 2008. Source: BGR, Raw Materials Group, 2010.



Note: values above 2000 indicate a high level of corporate concentration.

[15] http://info.worldbank.org/governance/wgi/index.asp

Another factor that determines the supply risks, relates to the *potential to substitute* the raw material by another one. Hence, the supply risks of a certain raw material will only fully impact on the EU economy if the raw material cannot be substituted. For this reason a substitutability index was introduced. The substitutability index for a specific raw material is an aggregate of substitutability indices for each of its uses. It is at the level of each use that substitution has been evaluated for each raw material. Four values have been given "on the basis of expert opinion" by Fraunhofer ISI to measure the various degrees of substitutability: a value of 0 would mean that substitution is possible at no cost; 0.3 means that substitution is feasible at relatively low cost; 0.7 means that substitution is possible at high cost; and 1 means that substitution is not possible or very difficult.

The supply of raw materials is not only a matter of availability of primary but also secondary raw materials. Hence also the *recycling* rate is also considered. As recycled raw materials are another source of supply, the more a material is recycled in the EU the lower the supply risk and vice versa. There are many different definitions of recycling. One concerns the percentage of new metals or minerals content which is not derived from primary production. This is known as the Recycled Content (RC) rate.

Another narrower definition measures the raw material content finally recovered from recycled end-of-life products in relation to the original new material content when the products were put on the market. This is known as End of Life Recycling Rates (EOL-RR) and relates specifically to the potential to increase the recovery of raw materials from discarded products. It measures the true recycling efficiency over the entire lifetime of a product (group). For the purpose of this assessment, the RC rate was used although slightly modified to exclude the flow of raw materials directly recycled from the processing phase.

It is acknowledged, however, that consideration of recycling in this way does not allow assessment of the supply risks associated with the fact that recyclable materials arising in the EU (the “urban” mine) may be exported. This leads to reduced access to local resources and thus a risk of not accessing EU secondary raw materials. It should also to be noted that although the recycling rate for most industrial minerals seems to be very low or nil, many of these materials are being recovered indirectly. For example, feldspar as such is not being recycled, but there is a lot of recycling of glass, which contains feldspar, and consequently it is being recovered. This indirect recycling has not been taken into account in the measurement of criticality in this study.

Case study: Access to metal scrap on the international and EU market

As Europe is not endowed with large mineral resources, the EU non-ferrous and precious metal industry has traditionally turned to scrap for a substantial part of its feed supplies. Metallurgical expertise and know-how have developed to make the most out of process scrap and residues as well as old scrap arising from end-of-life products, the so-called "urban mine". The European market provides large amounts of old scrap as it is one of the most industrialised and largest consumer markets in the world. At the same time, the EU environmental legislation has triggered increasing scrap recovery and growing energy concerns have highlighted the energy savings that can be derived from scrap recycling.

However, over the past few decades the EU non-ferrous and precious metal industry has been confronted with growing difficulties in accessing this “urban mine”, particularly as regards copper, aluminium and precious metal-bearing scrap. Indeed, the EU has become a net exporter of non-ferrous metal scrap when it used to be a net importer two decades ago.

An explanation could be that the markets for these materials are distorted by unfair or illegal trade practices or by a lack of level playing field in scrap processing operations. High export taxes, various domestic subsidisation schemes, lenient state attitudes vis-à-vis fraudulent trade circuits, and unequal implementation and enforcement of environmentally sound management (ESM) principles in scrap recycling and processing have given the EU industry’s competitors a decisive purchasing edge on the international and EU scrap market, while impeding exports of scrap from third countries. These policies have created competitive distortions which it has so far proved difficult to address.

The WTO action by the EU, USA and Mexico against export restrictions imposed by China is an example of the determination of the EU to address illegal practices when they occur and enforce international trade law. However, changes will not occur overnight and the methods operated by certain countries for pursuing their industrial strategies will inevitably result in persisting competitive pressure on the non-ferrous metal scrap market.

The Group has examined whether the supply risks arising from this situation could be reflected in the quantitative approach. However, no meaningful solution to include supply risk arising from the EU’s exports of secondary raw materials has been found. The issue is therefore only highlighted qualitatively.

The supply risk therefore comprises the assessment of the political-economic stability of the producing countries, the level of concentration of production, the potential to substitute and the recycling rate. The way the different components are calculated and aggregated is set out in annex I.

Case study: competition to land in EU

Another important risk to the supply of minerals and metals within the EU relates to challenges regarding access to land.

Access to land is a key requirement for the extractive industries, but the areas available for extraction in the EU are being steadily squeezed out by other land uses, such as urban development, agriculture, and nature conservation. Nevertheless there remains a continuing need to develop new mines and quarries to replace exhausted deposits, and the conflict with other land uses might be exacerbated because the extractive industry is confined to locations which possess known and commercially viable deposits of minerals.

Extractive operations tend to involve a long and complex planning stage and large investments of capital with long payback periods. This requires policy measures to streamline the administrative conditions and speed up the permitting process for exploration and extraction activities, while properly fulfilling applicable legal requirements.

Currently most Member States lack a national minerals policy which would cover all parts of the permitting process and link them to land-use planning policies. As minerals policies are not necessarily reflected in the land-use planning procedure, it is a matter of local competence how competitive land-use issues are ranked. This may lead to decisions inconsistent with the national priorities and with the general need to exploit deposits to ensure continuity of supply. Moreover, the requirements related to nature protection to reduce the loss of biodiversity and the implementation of the precautionary principle are additional challenges for a balanced national land-use policy.

The Group has examined whether a specific indicator could be developed to measure supply risks related to competing land uses within the EU. However, no appropriate indicator could be identified. Given the importance of these issues, particular problems of this type related to individual materials are highlighted in the profiles (annex V). It is recommended that further analysis should be undertaken to establish an indicator of land use competition with a view to including it in the methodology for assessing criticality in the future.

It is also worth noting that another working group of the Raw Materials Supply Group has been set up in order to identify and exchange best practice examples on how to facilitate access to land and extraction among Member States.

2.3.3 Environmental country risk

A third dimension relates to the environmental country risk, more precisely the risks that measures might be taken by countries with the intention of protecting the environment and by doing so endangering the supply of raw materials to the European Union.

Case study: trade aspects of environmental protection

The right of every country to regulate, limit or forbid the exploitation of its natural resources as a matter of national sovereignty is fully recognised in the European Union, provided these measures are taken in full conformity with the applicable international commitments, including *inter alia* commitments taken in the trade policy field.

For WTO members in particular, GATT Article XX provides a clear framework for setting up trade restrictive measures in relation with "the conservation of exhaustible natural resources". Measures taken on this legal basis should both comply with the Article XX "chapeau" (measures should be applied in a non-discriminatory manner and should not constitute a disguised restriction of international trade) and with paragraph (g), stating that such measures should be "made effective in conjunction with restriction on domestic production and consumption". Indeed, in light of a conservation objective it is imperative that trade restrictions actually lead to a decline in domestic production. However, the link between a reduction in exports and reduction in domestic production is far from straightforward.

Thus the EU will continue to monitor that trade restrictive measures taken by WTO members to protect the environment are indeed in line with GATT Article XX, rather than being used as tools aimed at providing domestic industry with privileged access to raw materials while discriminating against foreign operators and jeopardising the level playing field that is to be expected among WTO members..

In the calculations of the environmental country risks of each raw material, the "Environmental Performance Indexes" (EPI) for the producing country, which is co-developed by the Joint Research Centre, have been aggregated using the production figures as weight. This index ranks 163 countries on 25 performance indicators tracked across ten policy categories covering both environmental public health and ecosystem vitality. These indicators provide a gauge at a national government scale of how close countries are to established environmental policy goals. The overall EPI rankings provide an indicative sense of which countries are doing best against the array of environmental pressures that every nation faces. As for the supply risks, the level of concentration of production, the potential to substitute and recycling have also been taken into account. The way in which the different components have been combined is explained in Annex I.

Case study: environmental impacts of raw materials

In order to specify the environmental risk indicator it was felt appropriate to consider the environmental impacts of each raw material through the use of Life Cycle Assessment (LCA) data. A Life Cycle Assessment is based on the listing and quantification of all flows coming in and out of the system considered, including extraction, processing, transport, end-of-life recovery/recycling, etc. The listings of incoming and outgoing flows are called Life Cycle Inventories (LCI).

With this objective in mind, the Commission tasked Bio Intelligence in November 2009 to constitute an LCI database for 30 raw materials on the basis of available information, gather or generate LCI data for the 9 other materials to complement this, check the quality of the data and aggregate the data into a single environmental impact index for each material.

Consideration of inventory data will result in a large list of incoming and outgoing flows. This is aggregated in terms of associated impact indicators through Life Cycle Impact Assessment (LCIA). The environmental impact indicators for a material should be based on twelve impact indicators: depletion of abiotic resources, land use competition, climate change, stratospheric ozone depletion, human toxicity, freshwater aquatic ecotoxicity, maritime aquatic ecotoxicity, terrestrial ecotoxicity, photochemical oxidation (*summer smog*), acidification potential, eutrophication and ionising radiation.

In its final report[16] Bio Intelligence stated that no LCI data could be found for beryllium, diatomite, germanium, niobium and rhenium. It also underlined the following fundamental limitations inherent in the approach:

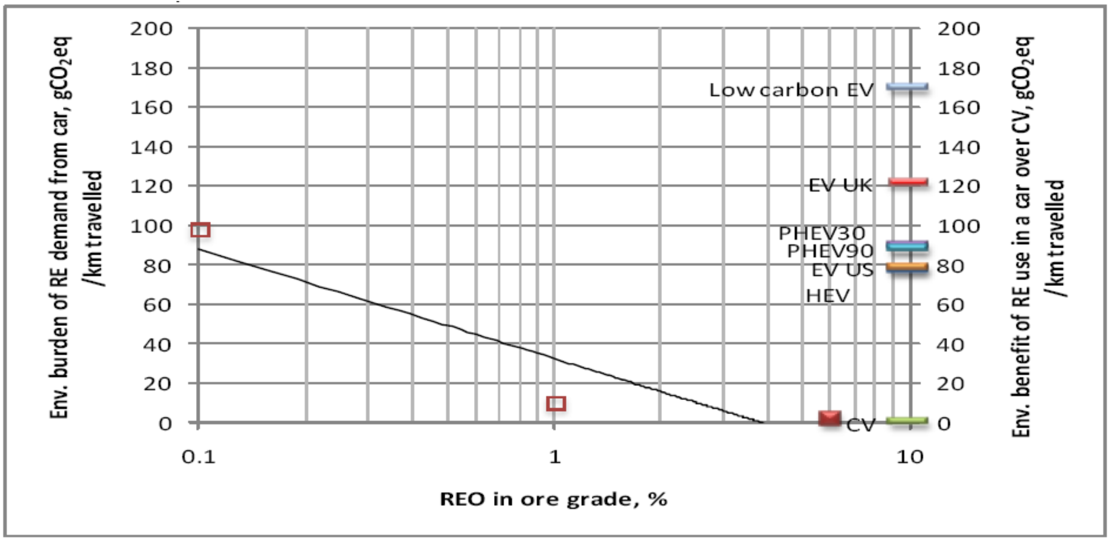
1) The study was limited to the production of a quantity of a material related to the functional unit "1 kg of raw material". The 39 materials cannot be compared with each other on the basis of the life cycle data alone because they do not have the same function and the same applications. This may lead to erroneous conclusions.

2) Moreover, the available data do not represent a "cradle-to-grave" approach, but a "cradle-to-gate". This means that the use phase and end of life are not being considered. Analysis of the use phase could lead to substantially different conclusions in relation to the assessment of the environmental impacts, in particular as some materials play an important role in green technologies that contribute to reducing greenhouse gas emissions and improving energy efficiency. The report clearly states that it is not sufficient to study only the impacts of production phase, and that the use phase and end of life impacts should also be considered.

This is for example illustrated by comparing the environmental benefit over a vehicle's life of using rare earth elements such as lanthanum and neodymium to the additional environmental burden of mining these materials over a range of possible concentrations in the ore body. The environmental burden, resp. benefit, is measured through the quantity of C02 emitted, resp. saved. Figure 6 illustrates the situation. On the right Y axis, the environmental benefits of electric vehicles (EV), hybrid and electric vehicles (HEV) or plug-in hybrid electrical vehicles (PHEV) are shown in comparison to conventional vehicles (CV). The environmental burden measured on the left Y axis depends on the ore grade. The higher the grade, the lower the burden. The figure suggests that, for all non-conventional vehicles (except the US electrical vehicles), the environmental benefit outweigh the impacts of exploitation as soon as the ore grade is higher than 0.1%. For the US electrical vehicles, this is the case for an ore grade above 0.2%.

[16] « Environmental impacts of some raw materials through LCA methods ». For the European Commission. Bio Intelligence. April 2010.

Figure 6: carbon burden-benefit analysis of utilising rare earths in hybrid and electric vehicles against REO[17] content in ore body. Source: “Lanthanides Resources and alternatives”. Reproduced with permission by Oakdene Hollins, UK. March 2010



PGMs provide another illustration of this issue. Due to the low ore concentration (< 10 g/t) and often difficult mining conditions primary PGM production is very energy intensive. According to the Ecoinvent 2.0 database of ETH Zurich/EMPA over 10000 tonnes of CO_2 are generated per tonne of PGM on average. In contrast, the CO2 impact of state of the art PGM recycling is only a fraction of the primary production, which is related to the much higher concentrations in products (e.g. 2000 g/t in autocatalyst ceramic). But in their use phase, PGMs have very positive effects on the environment. Catalysts have reduced tailpipe emissions of cars, such as nitrogen oxide (NOx), carbon monoxide (CO), and hydrocarbons (HC) by more than 90%. With current technologies, lower standards than today can practically only be reached by the application of PGM-based catalysts.

In addition, the report highlighted the fact that the use of a single aggregated indicator for environmental impact is not recommended.

On the basis of the findings of the Bio Intelligence study and due to the controversial nature of including LCA data from cradle to gate, the Group decided not to include LCA data in the methodology used to assess criticality. Therefore the definition of criticality does not take into account the environmental impacts of raw materials during their life cycle in, this report. However, in view of the importance of the potential application of the “cradle to grave” approach, it is recommended that further work should be developed with the aim of overcoming the current data constraints.

[17] Rare Earth Oxide: the oxide (ore) of a Rare Earth metal

2.3.4 Defining the criticality

To qualify as critical, a raw material must face high risks with regard to access to it, i.e. high supply risks or high environmental risks, and be of high economic importance. In such a case, the likelihood that impediments to access occur is relatively high and impacts for the whole EU economy would be relatively significant.

The thresholds used to distinguish high from lower supply and environmental risks or economic importance have been determined pragmatically and inevitably involve a certain judgment as there is no unequivocal methodology in this domain. It appears, in fact, that the cluster of points representing each raw material in a three dimension diagram could be relatively easily separated into sub-clusters: one with relatively high economic importance and risks, and the others with lower economic importance or risks.
It should be stressed that the distinction between "critical" raw materials and other raw materials is the result of a relative, rather than an absolute, assessment and that the quantitative methodology not only restricts inevitably the number of factors that can be taken into consideration but also that this assessment provides only a static view of the situation. In particular, it is important to note that the supply risks for some raw materials can change relatively rapidly.

Furthermore, although the economic importance might have been assessed on the basis of future demand, the Group decided to base its analysis on current figures in order to avoid using any debatable forecasts. However analyses of technology developments have been carried out with the view to describing potential evolution in the use of raw materials and qualifying the quantitative approach.

Applying this quantitative methodology (as described in annex I), was done on the basis of comprehensive data collection. With the technical assistance of Fraunhofer ISI publicly available data was used as much as possible, which was in turn complemented by expert opinions. In view of the confidential nature of some of the data provided by companies and/or associations, such data were used in an aggregated way.

In view of the limitations of any quantitative method, it was considered necessary to complement this approach with a qualitative assessment, describing the various issues that constitute the challenges of accessing raw materials for the EU, from technology developments to market distortions and any other factors of relevance to each raw material.

Assessing criticality of raw materials is not an absolute science, but it does provide an overall picture of issues that are driving the access to raw materials.

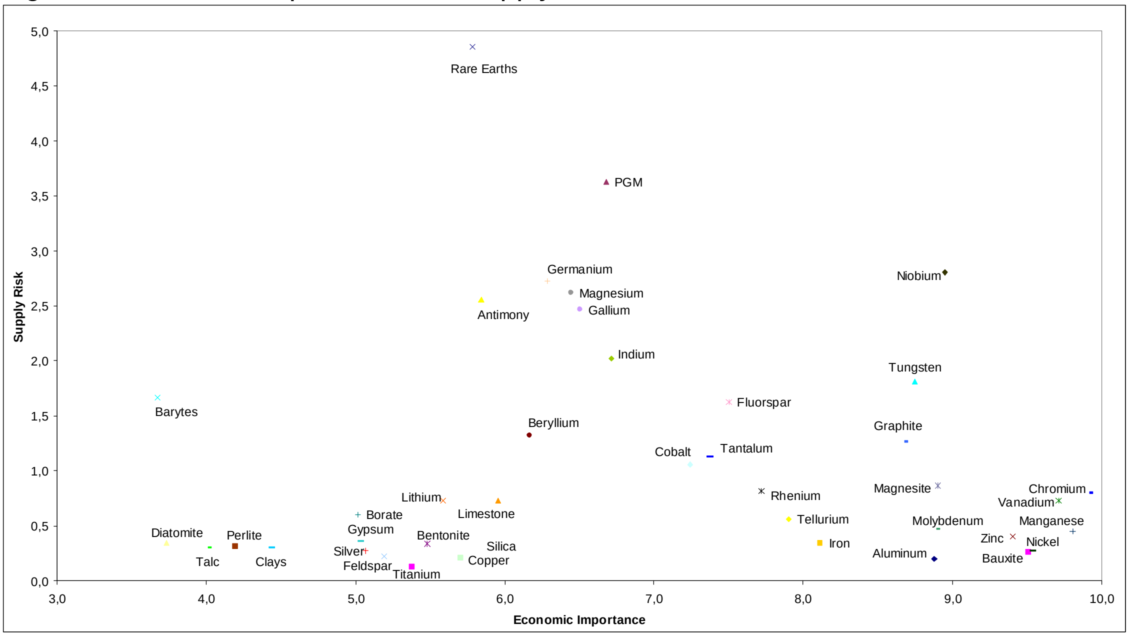
3. RESULTS AND LIST OF CRITICAL RAW MATERIALS

3.1 Economic importance and supply risks

Based on the methodology set out in the previous chapter, calculations have been made for the 41 raw materials. Figure 7 combines the results for economic importance and supply risks.

The X-axis reflects the positioning of the material in relation to its importance to the EU economy. The results range from very low (talc) to very high (manganese). The fact that materials such as beryllium are positioned towards the left side of the chart does not mean that these materials are less important than those on the right side. What it does suggest is that in case of supply restrictions for the latter, the potential impact could affect a larger part of the economic value chain in terms of value added than other materials. However, even in cases of "low" economic importance, one should bear in mind that the occurrence of supply problems for these materials could present a major problem to the development of very specific applications in the economy.

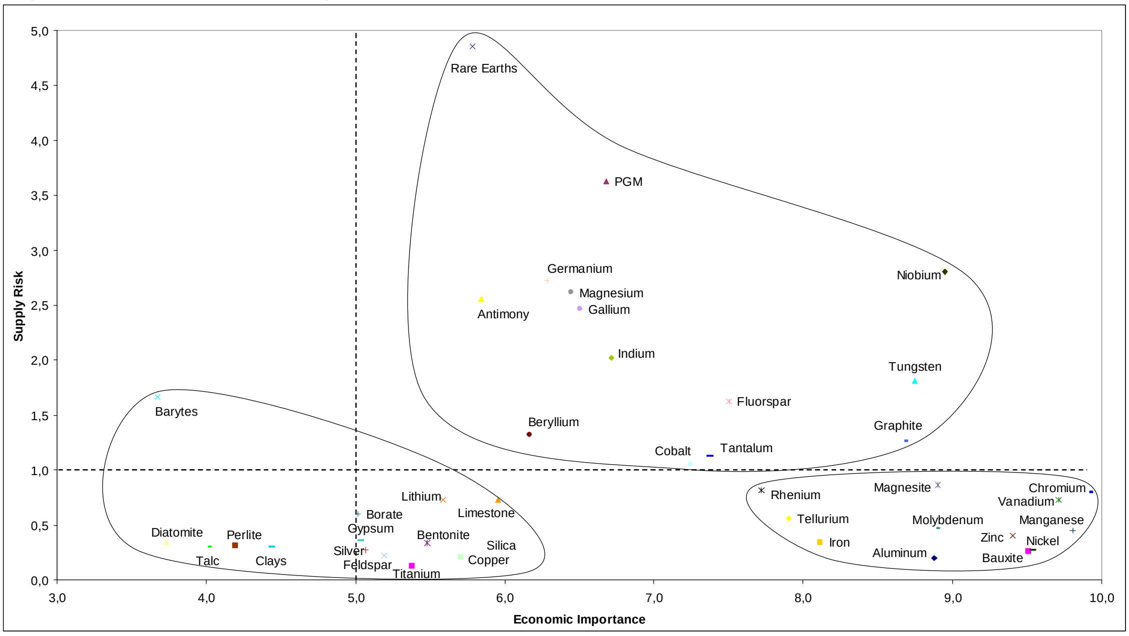
Figure 7: economic importance and supply risk of the 41 materials



The Y-axis reflects the positioning of the materials in relation to the supply risks that have been identified. The production of a material in few countries marked by political and economic instability, coupled to a low recycling rate and low substitutability, will result in a very high supply risk. The results range from very low (titanium) to very high (rare earths).

Three sub-clusters of points (one point for each raw material) can be distinguished as illustrated in figure 8.

Figure 8: sub-clusters of points



The cluster in the top right corner can be implicitly delimited with horizontal and vertical lines that are the thresholds above which the raw materials are considered as critical.

A number of materials are positioned in the top right corner of the figure in a separate sub-cluster of points. The Group regards the 14 raw materials falling within this sub-cluster as critical, because they are of high economic importance and have a high supply risk (see Annex I). Their high supply risk is mainly due to the fact that a high share of the worldwide production comes from China (antimony, fluorspar, gallium, germanium, graphite, indium, magnesium, rare earths, tungsten), Russia (PGM), the Democratic Republic of Congo (cobalt, tantalum) and Brazil (niobium and tantalum). This production concentration, in many cases, is compounded by low substitutability and low recycling rates. In this category, some critical raw materials actually comprise groups of raw materials: for example, PGM (platinum group metals) and rare earths include 6 and 17 raw materials respectively.

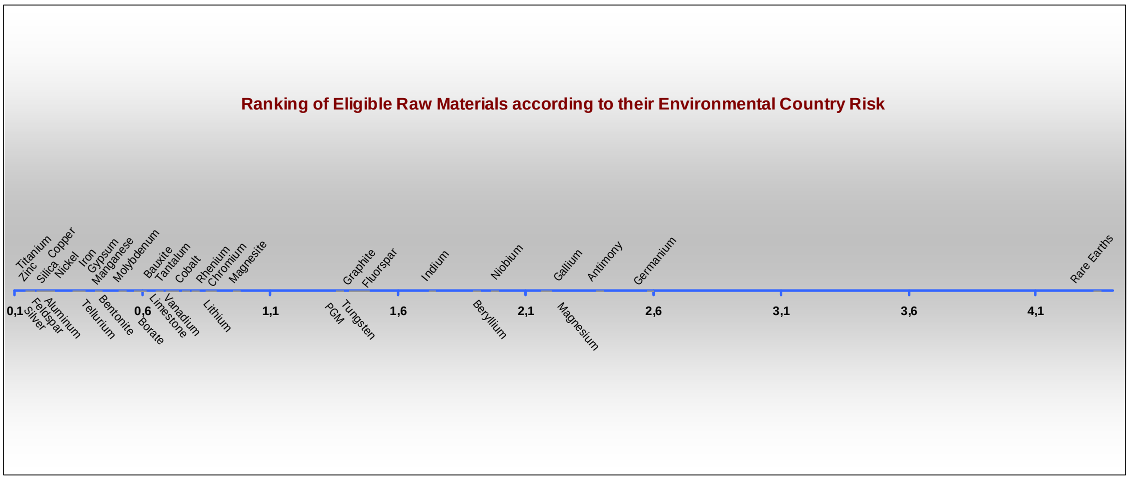
The materials positioned in the sub-cluster in the lower right corner are those that also have a high degree of economic importance, but have a relatively low(er) level of supply risk. It is stressed that a small shift in one of the parameters of the supply risk metric (e.g. level of concentration or political stability of producing countries) may result in a sudden change upwards. In order words, a slight change in the underlying variables may result in one of these materials being reclassified as 'critical'. This is particularly the case for rhenium, and tellurium. It should also be noted that the raw materials ranked with the highest economic importance (manganese, vanadium and chromium) are mainly used in the steel production sector. This might result from an overestimation of the value added of the value chain of these raw materials measured through the megasector "metals".

The materials positioned in the sub-cluster in the lower left corner are materials that have relatively lower economic importance and supply risks. For some of them, notably the industrial minerals, the group considers that possible supply risks may occur within a longer time horizon should competition to land continues to adversely affects production from quarries or mines in the EU.

3.2 Environmental country risks

In the previous section the different materials have been assessed in relation to supply risks and economic importance. In a second phase environmental country risks were considered to identify possible additions to the list of critical raw materials. To reiterate, in the methodology used, either high supply risk or environmental country risk is sufficient to qualify a raw material for criticality, provided that its economic importance is above the threshold. Figure 9 sets out the environmental risk for those materials which are economically important (i.e. above the threshold) thus eligible for criticality. On the basis of this figure there appears a subgroup of materials with high environmental country risks (over the threshold of 1.2). All of these materials are already considered to be critical in view of their supply risks, so it means that no materials would need to be added to the list of critical raw materials on the basis solely of high environmental country risk.

Figure 9: Ranking of eligible raw materials according to their environmental country risk



3.3 List of critical raw materials for the European Union

The analysis resulted in the following (alphabetical) list of critical raw materials at EU level:

- Antimony
- Beryllium
- Cobalt
- Fluorspar
- Gallium
- Germanium
- Graphite
- Indium
- Magnesium
- Niobium
- PGMs (Platinum Group Metals)
- Rare earths
- Tantalum
- Tungsten

The Platinum Group Metals (PGMs) comprises platinum, palladium, iridium, rhodium, ruthenium and osmium.

Rare earths include yttrium, scandium, and the so-called lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium)

Specific assessments for each of these materials are given in the individual profiles (annex V). The main reasons for their criticality ratings are summarised here.

<u>Antimony</u>

- no effective substitute for its major application (flame retardant)
- metal supply (the raw material for EU antimony value chain) dominated by China which also has the largest reserves of antimony ore worldwide à high risks of quantitative and price disruption
- low recycling due to dissipative nature of major usage
- worldwide loss of know-how in flame retardants if EU antimony value chain is destroyed

<u>Beryllium</u>

- about 99% of world production originates in US and China
- low recycling rate
- difficult to substitute and where there are possibilities there may be a loss of performance

<u>Cobalt</u>

- DRC has a large share of world production
- lack of level playing field regarding primary production, particularly Chinese competition
- limited options for substitution

Fluorspar

- 25% of the fluorspar consumption of the EU is covered by domestic production, the rest was imported, to a large extent from China which also applies export quota and export taxes
- recycling rate is estimated to be below 1% in the EU
- substitution possibilities appear to be limited

Gallium

- China is the main producer (75%), while in the EU there is also some production in Hungary and Slovakia
- South-Africa, China and Russia impose trade restrictions related to gallium
- gallium is currently not being recycled from old scrap
- there are substitutes for gallium only for certain applications

Germanium

- not recovered within the EU, though imported ores are refined and germanium metal is exported. EU is highly dependent on imports from China, which accounted for over 71% of world production in 2009
- only about 30% is recycled

Graphite

- EU is up to 95% dependent on imports, mainly from China
- recycling is very limited while the abundance of graphite on the world market inhibits increased recycling efforts

Indium

- more than 81% of the EU's imports of indium originate in China
- recycling possibilities for indium are limited mainly to manufacturing residues, whereas substitution is possible in some applications only

Magnesium

- EU imports almost 47% of the world's production of magnesium. China is by far the largest producer of magnesium in the world, with almost 93% of the world's production
- China, Russia and South Africa impose trade restrictions
- recycling possibilities for magnesium are limited

Niobium

- there is no production in the EU. More than 92% of niobium is produced in Brazil, and 7% in Canada
- the estimated recycled share of the total consumption is 20%. Although substitution of niobium is possible, it may involve higher costs and/or a loss in performance.

PGM (Platinum Group Metals)

- there is no primary production in the EU. The main sources for PGM for the EU are South Africa (about 60%) and the Russian Federation (over 30%)
- due to the open character of their lifecycles, the recovery of PGMs from consumer products is still limited. In Europe the level of recovery of PGMs used in automotive catalysts remains well below 50%, whereas for electronic applications it is only about 10%. The challenge in PGMs in consumer applications is the collection and channeling through the recycling chain to the metal recovery processes. To a certain extent, PGMs are also used in a rather dissipative way which puts economic and technical challenges on recycling.
- PGMs 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

- not produced within the European Union. China accounted for 97% of world production in 2009. Moreover, China applied export restrictions and quota for rare earths
- new mine projects are underway in other countries, but besides the time span required to (re)open up a mine for production, there are a number of added complexities specific to rare earth extraction
- although recovery processes relevant to rare earths have been developed, none of them is currently commercially viable. For most applications substitutes for rare earths are available but with loss of performance.

Tantalum

- large share of production in DRC
- recycling is limited
- difficult to substitute and where there are possibilities there may be a loss of performance.

Tungsten

- raw material supply (APT, oxide) dominated by China which also has the largest reserves of tungsten ore worldwide à high risks of quantitative and price disruption.
- growing risks of "predatory" behaviour of China on the tungsten scrap market
- substitution possibilities limited by cost of alternative materials/technologies, lesser performance, and less environmental friendly alternatives.
- worldwide loss of know-how if EU tungsten value chain is destroyed as it is the leader in the development of many tungsten products development for automotive, aerospace, medical, lighting applications -> disappearance of EU tungsten industry would result in full dependence of several key industries on imports from abroad.

3.4 Future perspectives and potential evolution of criticality

3.4.1 Future perspectives on raw material demand – implications of technological change

Criticality is influenced by a group of different parameters. Given the 10 years time horizon of this study, it is very important to note that many of those parameters are not stable and are subject to a process of constant change. One of the most powerful forces influencing the criticality of raw materials is technological change. The rapid diffusion of new technologies can increase the demand for certain raw materials, while decreasing the demand for others, if their technology becomes obsolete. For the purposes of this report, it is important to assess the future raw material demand generated by new technologies, because the ability to develop, produce, market and make use of new technologies is important for the future economic and technological development of the EU.

In order to assess whether the availability of raw materials might become a restriction for economic and technological development, the German Federal Ministry of Economics and Technology (BMWi) commissioned a report which analysed the influence of material-intensive emerging technologies on raw material consumption.[18] Recently the indicators developed in this study have been updated by the BGR[19].

Material-efficient economic activity depends on an extraordinary variety of raw materials applications in industrial sectors, the technologies used there and the products they manufacture. The question to answer is how future uses of emerging technologies, which at present are often still at the developmental or pilot stage, will drive the demand for raw materials and on which raw materials these innovations may be especially reliant. Emerging technologies are industrially applicable technical capabilities which stimulate revolutionary innovation pushed far beyond the borders of individual industrial sectors and change the very fabric of economic structures, social life and the environment in the long term. Advances in innovation can affect individual technologies such as fuel cells, for example, organic light-emitting diodes, or Radio Frequency Identification (RFID) labels.

Systemic advances are also possible when known technologies are used for new applications. Examples here are hybrid cars, or the thermo-chemical production of synthetic fuels from biomass. Coping with and marketing emerging technologies is particularly important for industry and its global competitiveness. Emerging technologies cannot be narrowed down to 5, 10 or 20 innovations.
A fundamental rejuvenation of national economies is taking place in all sectors driven by the goal of high-wage, industrialised countries to hold their own place in global competition via technological excellence.

In the study commissioned by BMWi the analysed technologies and raw materials were limited to a workable number. The raw materials were selected on the basis of an estimation of their significance for technology development and limited to inorganic,

---

[18] Angerer et al.
[19] BGR, Elsner, H., Melcher, F.; Schwarz-Schampera, U., Buchholz, P.: Elektronikmetalle - zukünftig steigender Bedarf bei unzureichender Versorgungslage? Hannover, 2010

mineral raw materials which are not utilised for energy purposes. Only metal and semi-metal raw materials were included because Germany as well as Europe is almost completely dependent on imports of these materials.

Table 2 The raw materials analysed[20]

Commodities	Specialities
Antimony	Platinum group metals (Pt, Pd, Ru, Rh, Os, Ir)
Chromium	Silver
Cobalt	Rare earth elements (Sc, Y, Nd)
Copper	Indium
Niobium	Germanium
Tantalum	Gallium
Titanium	

When selecting the technologies, priority was given to innovations assumed to trigger noticeable impulses on the demand for raw materials. The results provide an informative illustration of the future for the selected portfolio of raw materials and technologies (table3).

These emerging technologies were analysed on a global level. Nevertheless, they are of significance to the EU. Indeed, it seems to be clear that Europe cannot sit on the sidelines while other regions develop markets for these technologies. Furthermore even when it seemed that the know-how of a specific technology in Europe is lower than in other countries, it was suggested that R&D projects and market programmes should be funded in order to promote the global leadership, as it is now held by the EU in the field of large lithium ion batteries.

[20] List of raw materials analysed in the BMWi analysis which are also analysed in this report

Table 3 The portfolio of emerging technologies analysed

Automotive engineering, aerospace industry, traffic engineering	1. Light-gauge steel with tailored blanks 2. Electric traction motors for vehicles 3. Fuel cells electric vehicles 4. Super capacitors for motor vehicles 5. Scandium alloys for constructing lightweight airframes
Information and communication technology, optical technologies, micro technologies	6. Lead-free solders 7. RFID – Radio Frequency Identification 8. Indium-Tin-Oxide (ITO) in display technology 9. Infrared detectors in night vision equipment 10. White LED 11. Fiber optic cable 12. Microelectronic capacitors 13. High performance microchips
Energy, electrical and drive engineering	14. Ultraefficient industrial electric motors 15. Thermoelectric generators 16. Dye-sensitized solar cells 17. Thin layer photovoltaics 18. Solarthermal power stations 19. Stationary fuel cells – SOFC 20. CCS – Carbon Capture and Storage 21. High performance lithium-ion batteries 22. Redox flow batteries for electricity storage 23. Vacuum insulation
Chemical, process, production and environmental technology, mechanical engineering	24. Synthetic fuels 25. Seawater desalination 26. Solid state lasers for industrial applications 27. Nano-silver
Medical engineering	28. Orthopaedic implants 29. Medical tomography
Materials technology	30. Superalloys 31. High-temperature superconductors 32. High performance permanent magnets

3.4.2 Emerging technologies and raw materials

The analysis of how raw material demand is driven by the use of new technologies clearly reveals the influence of technological change on criticality. Table 4 shows the raw material demand for the analysed emerging technologies related to today's total world production of the specific raw material. The figures for raw material demand from emerging technologies in 2006 (ETRD 2006) show the share of world production of the specific raw material which is taken up by emerging technologies. The figures for 2030 show the share of today's world production of the specific raw material that will be required for these technologies in 2030. The latter is an indicator of the demand for expanding mining capacity stemming from emerging technologies. The indicator has a factor of approximately 4 for gallium and 3.3 for indium. This means that the demand emanating from foreseeable technical innovations for these two raw materials in 2030 will be 4 and 3.3 times respectively higher than the total amount produced in the world today. It also means that the demand from emerging technologies might increase by a factor of more than 20[21] for gallium between 2006 and 2030, and by a factor of 8, 8 and 7 for indium, germanium and neodymium, respectively, in the same period.

The indicator has a factor of 2.2 for germanium, 1.7 for neodymium (rare earth), 1.4 for platinum and 1 for tantalum. It is 0.8 for silver, 0.4 for cobalt, 0.3 for palladium and titanium, and 0.2 for copper. Because of the clearly visible dominance of technological change on the demand for raw materials here, these also constitute the raw materials of the project portfolio which are especially important for future technology development and use in marketable products.

Table 4**:** Global demand of the emerging technologies analysed for raw materials in 2006 and 2030 related to today's total world production of the specific raw material (Updated by BGR April 2010)

Raw material	**Production 2006** [1] **(t)**	**ETRD 2006 (t)**	**ETRD 2030 (t)**	**Indicator 2006**	**Indicator 2030**
Gallium	152 [6]	28	603	0,18 [1]	**3,97** [1]
Indium	581	234	1.911	0,40 [1]	**3,29** [1]
Germanium	100	28	220	0,28 [1]	**2,20** [1]
Neodymium[7]	16.800	4.000	27.900	0,23 [1]	**1,66** [1]
Platinum[8]	255	very small	345	0	1,35 [1]
Tantalum	1.384	551	1.410	0,40 [1]	**1,02** [1]
Silver	19.051	5.342	15.823	0,28 [1]	0,83 [1]
Cobalt	62.279	12.820	26.860	0,21 [1]	0,43 [1]
Palladium[8]	267	23	77	0,09 [1]	0,29 [1]
Titanium	7.211.000 [3]	15.397	58.148	0,08	0,29
Copper	15.093.000	1.410.000	3.696.070	0,09	0,24
Ruthenium[8]	29 [4]	0	1	0	0,03
Niobium	44.531	288	1.410	0,01	0,03
Antimony	172.223	28	71	<0,01	<0,01
Chromium	19.825.713 [2]	11.250	41.900	<0,01	<0,01

ETRD = Emerging Technologies Raw Material Demand

[1] Data updated by the BGR based on new information [2] Chromite [3] Ore concentrate [4] Consumption
[6] Estimation of full production in China and Russia [7] rare earth [8] platinum group metals

[21] Ratio of 3,97 to 0,18

Table 5: Raw materials and their driving emerging technologies

Raw material	Emerging technologies (selected)
Gallium	Thin layer photovoltaics, IC, WLED
Neodymium	Permanent magnets, laser technology
Indium	Displays, thin layer photovoltaics
Germanium	Fibre optic cable, IR optical technologies
Platinum	Fuel cells, catalysts
Tantalum	Micro capacitors, medical technology
Silver	RFID, lead-free soft solder
Cobalt	Lithium-ion batteries, synthetic fuels
Palladium	Catalysts, seawater desalination
Titanium	Seawater desalination, implants
Copper	Efficient electric motors, RFID
Niobium	Micro capacitors, ferroalloys
Antimony	ATO, micro capacitors
Chromium	Seawater desalination, marine technologies

In contrast, there are other technical innovations which only have marginal impacts on the future demand for raw materials. For example, orthopaedic implant production is a strongly growing market in an ageing society. However, this does not have significant impact on raw materials demand. Similarly, the emerging technology of dye-sensitized solar cells has hardly any effect on raw material demand.

The drivers of the world economy

A factor which has not been taken into account is the growth of the world economy. The world economy has jumped from the moderate average growth of 3.8 % per year experienced over the last twenty years up to 5 % per year since 2004, mainly pushed by China's economic growth. However it declined to 3% in 2008 and to 1.1% in 2009 because of the economic crisis. If a future growth rate of 3.8 % is assumed, the world economic output in 2030 will still be 2.4 times that of 2006. Consequently, in addition to the influence of technological change, this economic growth will lead to increased future demand of raw materials.

Case study: The use of raw materials in future applications for rechargeable batteries[22]

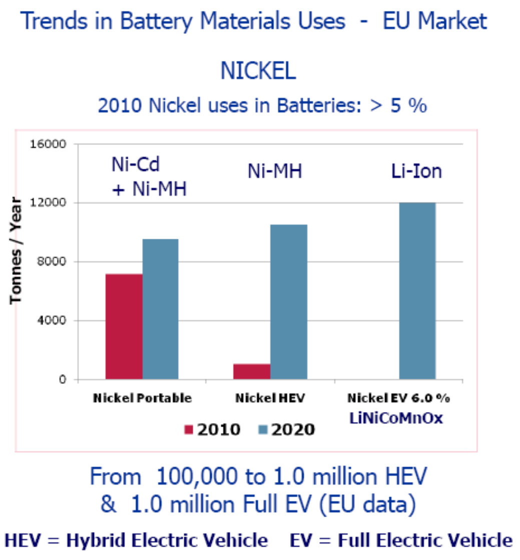
During the next decade, the demand for high performance rechargeable batteries will increase as a result of the market evolution of the electrical and electronic portable equipment and of the electric vehicle market.

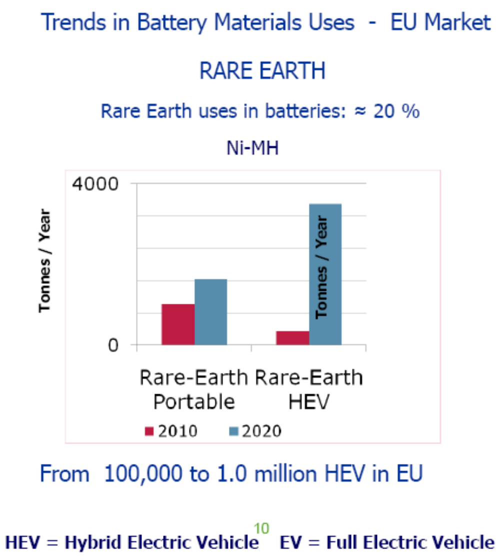
In the markets for portable electronic equipment and other cordless equipment, the sustained demand for rechargeable batteries observed over the last ten years should continue. The growth rate in materials demand is thus expected to reach 5% per year over the next decade. This will require an increasing use of rare earths, as well as nickel, cobalt and lithium (notably nickel- and cobalt-based specialty chemicals, and lithiated metallic oxides).

Given the greater uncertainty associated with the development of the electric vehicle being more speculative, a conservative evolution has been assumed. The resulting demand for rare earths, nickel, cobalt and lithium is based on a production of 1.0 million electric or hybrid electric vehicles in 2020.

Figures 10 displays the evolution of tonnes of rare earths, nickel, cobalt and lithium contained in portable batteries used in the EU between 2010 and 2020. Their tonnage in portable batteries might be multiplied by a factor of three to four for rare earths and nickel, up to about six for cobalt, and more than ten for lithium.

Figures 10



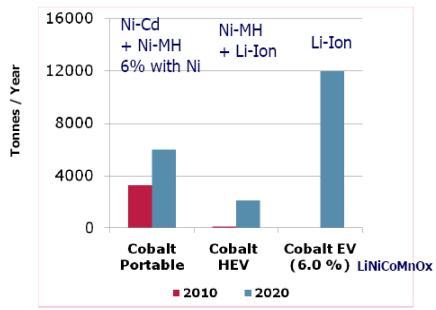


[22] The results reported in this box are extracted from a presentation entitled "A case study on rechargeable batteries" prepared by RECHARGE and UMICORE for a workshop organised by the European Commission (DG Enterprises) and Eurometaux on the 19th of April 2010.

Trends in Battery Materials Uses - EU Market

COBALT

2010 Cobalt uses in Batteries: ≈ 20 %

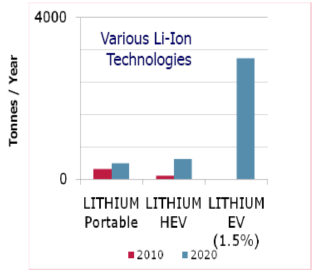


From 100,000 to 1.0 million HEV and & 1.0 million Full EV (in EU)

Trends in Battery Materials Uses - EU Market

LITHIUM

2010 Lithium uses in batteries: > 25 %



From 100,000 to 1.0 million HEV and & 1.0 million Full EV (in EU)

For rare earths, cobalt and lithium batteries represent today up to 25% of the current uses of these raw materials. An imbalance between supply and demand may occur during the market development of the e-mobility in the next ten years. The recycling of raw materials from these batteries will be essential in the EU to prevent tension, even if the long lifespan of batteries (the average life of vehicles is about seven years) will delay the availability of batteries for recycling and create gaps between the need for raw material and the availability of this source of secondary raw material.

Case study: Raw materials and electromobility

The currently expected market growth figures for electric vehicles repeatedly raise the question of whether the necessary raw materials are available.

The discussion often centres on lithium. But a recent study by Fraunhofer ISI shows, assuming a market penetration scenario in which electric cars make up 50 per cent of all newly registered private vehicles world-wide by 2050, that this will still only have consumed about 20 per cent of the global lithium resources. This scenario takes into account the use of recycled materials and lithium demand for other applications.

If the electric cars market takes off more quickly, e.g. assuming a market penetration scenario in which electric cars make up 85 per cent of all newly registered private vehicles world-wide by 2050, identified lithium resources would not be exhausted by 2050. However, those supplies which can be extracted using today's technologies and at today's lithium prices will be completely exhausted, meaning that new reserves would have to be tapped. To be on the safe side a recycling system for lithium should be set up at an early stage and research for new battery technologies should be continued.

The outcomes of the scenarios are shown in figures 11 and 12.

Figure 11: Uses of lithium cumulated [in t Li] – 50% penetration of electric cars in 2050

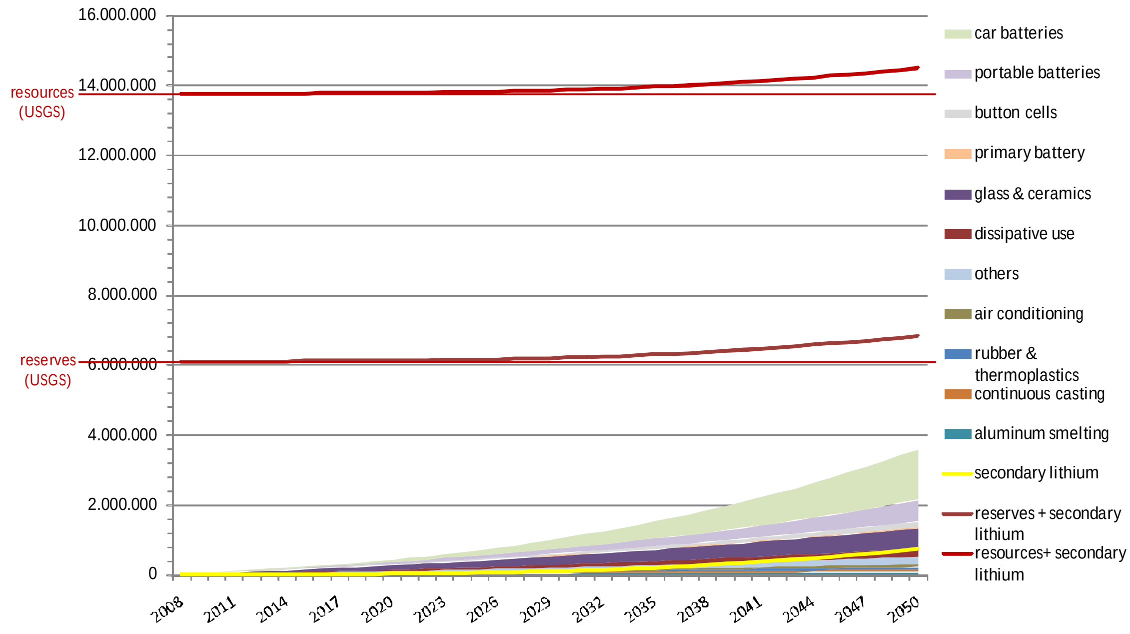
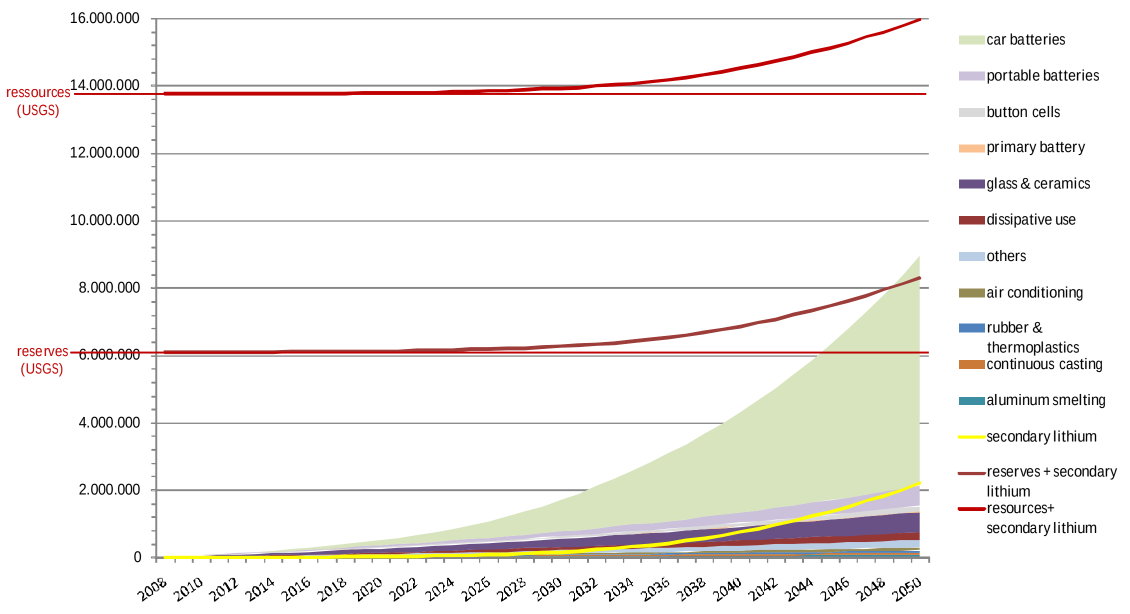


Figure 12 Uses of lithium cumulated [in t Li] – 85% penetration of electric cars in 2050



Source: Gerhard Angerer, Frank Marscheider-Weidemann, Matthias Wendl, Martin Wietschel (2009): Lithium für Zukunftstechnologien - Nachfrage und Angebot unter besonderer Berücksichtigung der Elektromobilität. ISI Berichte, Dezember 2009, Fraunhofer ISI.

4. RECOMMENDATIONS

This section outlines a number of operational recommendations for follow-up and support which are based on the lessons learned during this study. It also sets out recommendations in policy areas which are based on the results of the assessment and list of critical raw materials.

4.1 Recommendations for follow-up and further support

As the criticality assessment effectively provides a snapshot in time, it is advisable to update the list every 5 years. Considerations should also be given to the extent that the methodology could be applied to other non-energy raw materials.

Recommendation 1

The Group recommends that the list of EU critical raw materials should be updated every 5 years and that the scope of the criticality assessment should be increased.

During the work reported here the need for reliable, consistent data for various indicators became very apparent.

To underpin future criticality assessments, further work should be undertaken to gather more data and information on minerals and metals within the EU, notably through contributions by the network of geological surveys. The objective might be to prepare a European Raw Materials Yearbook with the involvement of national geological surveys and mining/processing/recycling industries. In this context the Report on best practices in the area of land use planning, and geological knowledge sharing and its recommendations should be fully exploited. Similarly synergies should be drawn from other initiatives carried out in the framework of the RMI notably in relation to the improvement of recycling data.

Beyond improving the availability of data in a structured way, further work is also recommended to improve the quality of certain data, such as the establishment of reliable statistical breakdown of manufacturing industry into value-added chains of manufacturing, and the flows of raw materials through the value added chains.

The need for further studies on certain issues also became apparent during the course of this work. In particular there are requirements to make analytical progress in life cycle assessment data for raw materials, and to better measure land use competition notably by establishing country indicators in the EU. More detailed specific studies on market concentration and emerging technologies are also recommended. Specific working groups could be set up to further analyse the emerging technologies with a high economic importance and their impacts on future demand of raw materials.

Recommendation 2

The Group recommends that steps be taken to:
- improve the availability of reliable, consistent statistical information in relation to raw materials;
- promote the dissemination of this information, notably by preparing a European Raw Materials Yearbook with the involvement of national geological surveys and mining/processing industries. It should focus on improving the knowledge of the availability of resources and on their flow into products through the value-added chains of the EU economies;
- establish indicators of competition to land in the Member States;
- encourage more research into life-cycle assessments for raw materials and their products on a “cradle-to-grave” basis;
- create a working group(s) to further analyse the impact of emerging technologies on demand of raw materials.

From an organisational point of view and to maintain a political momentum, the Raw Materials Supply Group should ensure follow-up of the criticality assessments through a sub-group, and identify a series of indicators to assess the evolution of the situation and the possible changes in the list of critical raw materials for the European Union

Recommendation 3

The Group recommends that a sub-group of the Raw Material Supply Group of the European Commission should be set up to ensure follow-up of this report on critical raw materials.

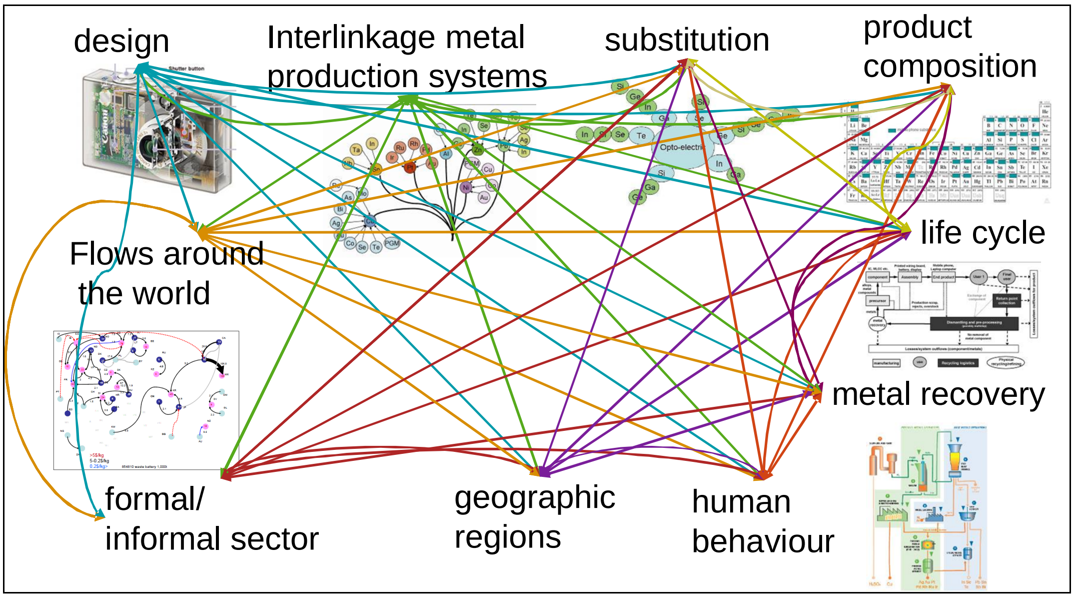
4.2 Policy-oriented recommendations to secure access to and material efficiency of critical raw materials

A combination and prioritisation of measures are needed to sustainably improve the access to resources and material efficiency. There is no “one size fits all” tool, but the most appropriate set of tools needs to be developed depending on the characteristics of the raw material concerned and the products derived from it.

To achieve this, a good understanding is needed of the drivers of criticality, product characteristics and the lifecycle of the processes and products. Some of the proposed measures may address technical or economic issues. Many measures are interdependent and in most cases an interdisciplinary approach is needed, as shown for metals in figure 13. Therefore the formulation of specific policy measures for a certain material would need to be developed on a case by case basis. In this section, the Group expresses recommendations on areas where measures should be undertaken. In order to respect the scope of its mandate, it refrains from specifying detailed actions.

The higher the import dependence of raw materials, the more important recycling, substitution and material efficiency become. However, such options are not always available, especially without some deterioration of the quality and performance of products. It is also important to note that improvements in recycling, substitution and material efficiency are constantly being sought by companies in order to enhance their economic and financial performance (through cost reduction and increased competitiveness).

Figure 13 Interdependence of measures – The case of metals



4.2.1 Mining and access to primary resources

Access to and extraction of primary raw materials will always be needed, especially in times of soaring demand due to a strong market growth or new applications. Even in cases of perfectly closed loops, i.e. with complete recycling, the gap between the time of product manufacturing and product end of life (EoL) phase needs to be bridged. This is the more significant the longer the lifetime of a product is and the stronger the market growth.

The quality of primary supply can differ significantly depending on the countries involved and the supplying company or trader. Such differences can exist for reasons of the quality of the ore body, the cost of production, the legislative framework, the environmental performance, all of which govern the material efficiency within the primary production chain (yields and range of raw materials recovered). Measures to improve primary supply should take this into consideration as well.

Recommendation 4

The Group recommends policy actions to improve access to primary resources aiming at:

- supporting the findings and recommendations resulting from the work carried out by the ad hoc working group on "Best practices in the area of land use planning and permitting" with a view to securing better access to land, fair treatment of extraction with other competing land uses and to developing a more streamlined permitting processes;
- promoting exploration and ensuring that exploration by companies is regarded as research activity;
- promoting research on mineral processing, extraction from old mine dumps, mineral extraction from deep deposits, and mineral exploration in general, notably through EU RTD Framework Programmes;
- promoting good governance, capacity-building and transparency in relation to the extractive industries in developing countries, notably in the area of critical raw materials;
- promoting sustainable exploration and extraction within and outside of the EU.

4.2.2. Level playing field in trade and investment

In order to ensure a sustainable supply of raw materials on global markets (including ores and concentrates, intermediate and precursor materials, scrap or unwrought metal), the establishment of a level playing-field in trade and investment and fair competition conditions should be pursued. This requires that the impact on the competitiveness of EU industry's products of such distortions and market disruption should be properly evaluated. This also requires to address trade distortions at multilateral and bilateral levels and to take appropriate measures to restore fair terms of competition in the markets.

Recommendation 5

The Group recommends that the following policy actions, with regard to trade and investment as defined in the trade raw materials strategy, be pursued:

- maintain current EU policy choices in the negotiation of bilateral and regional trade agreements;
- consider the merits of pursuing dispute settlement initiatives at WTO level so as to include in such initiatives more raw materials important for the EU industry; such actions may give rise to important case law so long as existing GATT rules lack clarity and are limited in scope;
- engage without reservation in consultations with third countries whose policies are causing distortions on international raw materials markets in order to discourage certain policy measures and to request adherence with market forces;
- foster an effective exchange-of-views on certain policies made within the institutional framework of EU economic cooperation agreements (e.g. with China on the latter country's NFM recycling plan to year 2015);
- continue to raise awareness on the economic impact of export restrictions on developing and developed countries in various multilateral fora, such as WTO or the OECD;

- consider shaping a new EU-wide policy on foreign investment agreements in such a manner as to better protect EU investments in raw materials abroad and ensure a level playing-field with other foreign investors who benefit from the backing of State funds;
- continue to increase coherence of EU policy with respect to raw materials supply, for example in the assessment of injurious dumping and subsidies.

4.2.3. Recycling

When possible, efficient recycling of EoL products and all kinds of production residues at various points in the lifecycle significantly reduces the demand for primary raw materials and thus alleviates the supply risks with which critical raw materials are faced. Moreover, in many cases it leads to savings in energy demand and hence reduces climate change impact. As in primary production, the technological and organisational capability as well as the economic and environmental performance of a recycling operation is crucial. The higher the import dependence on an individual metal, then the more important recycling becomes, especially if the possibilities for material substitution and savings in manufacturing are limited. It is noted that direct recycling of industrial minerals is usually not feasible since the mineral forms an intrinsic part of end-use application (glass, paper, ceramics, etc). However when economically and environmentally beneficial, the end products containing the industrial minerals may be recycled leading to the minerals recovery.

Recommendation 6

The Group recommends that policy actions are undertaken to make recycling of raw materials or raw material-containing products more efficient, in particular by:

- mobilising EoL products with critical raw materials for proper collection instead of stockpiling them in households (hibernating) or discarding them into landfill or incineration;.
- improving overall organisation, logistics and efficiency of recycling chains by focusing 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.

4.2.4. Substitution

For many of the identified (critical) raw materials, substitution is currently difficult to achieve without a deterioration in the quality or performance of the products, or is not economically viable. Potentially, *s*ubstitution is particularly adequate for dissipative use segments of critical raw materials, since here hardly any recycling opportunities exist.

Furthermore, substitution becomes very powerful where a potentially scarce and critical raw material could be substituted by an abundant one (e.g. indium by zinc), but it has little benefit if the substitute is critical itself (e.g. platinum by palladium or indium by germanium), or might become critical because of the substitution. Substitution can also aim beyond the material level. Instead of substituting one substance by another it may be more beneficial to analyse the product system itself and investigate whether a key product function could be achieved by a smarter product approach. It should also be noted that for each application of a particular raw material a different substitute materials may be required.

Recommendation 7

The Group recommends that substitution should be encouraged, notably by promoting research on substitutes for critical raw materials in different applications and to increase opportunities under EU RTD Framework Programmes.

4.2.5. Material efficiency

Material efficiency basically means that “more is produced from less”. In this way a smaller amount of material is needed to produce a product and those raw materials are kept in the use loop for a longer time once they have been extracted. Improvement in material efficiency is a constant objective of companies as they strive to improve their economic and financial performance (cost reduction and increased competitiveness).

Increase in material efficiency may result from improvement in the four main steps of product manufacturing, i.e. raw materials production, product manufacturing, use and end-of-life (EoL).

Each step usually contains a number of sub-processes from which losses into residues can occur. In primary metals production these sub-processes are, for example, exploration and extraction, ore beneficiation, and metal smelting and refining. Losses occur here due to non-extracted parts of an ore body, and because of metal losses into ore processing tailings, smelter slags and other process residues. The same is true for minerals.

At its end-of-life a product or the raw materials contained therein can be recycled and can replace primary raw materials. For many applications recycled metals can substitute for primary metals and thus reduce the demand for newly mined metals for many applications. The same may occur with industrial minerals, although in these cases the recycling generally concerns the product itself containing the minerals (e.g. silica sand is recycled through the recycling of glass).

The raw material production for metals can make use of a combination of primary and secondary sources and both pathways need to be understood as complementary. Whether the recycled metals are used in the same product group or in another application does not really matter, since both primary and secondary metals are traded on a global scale and any quantity of recycled metal directly impacts its demand supply balance. For most metals their recycling does not lead to deterioration in quality, meaning that in theory such cycles could continue forever.

Recommendation 8

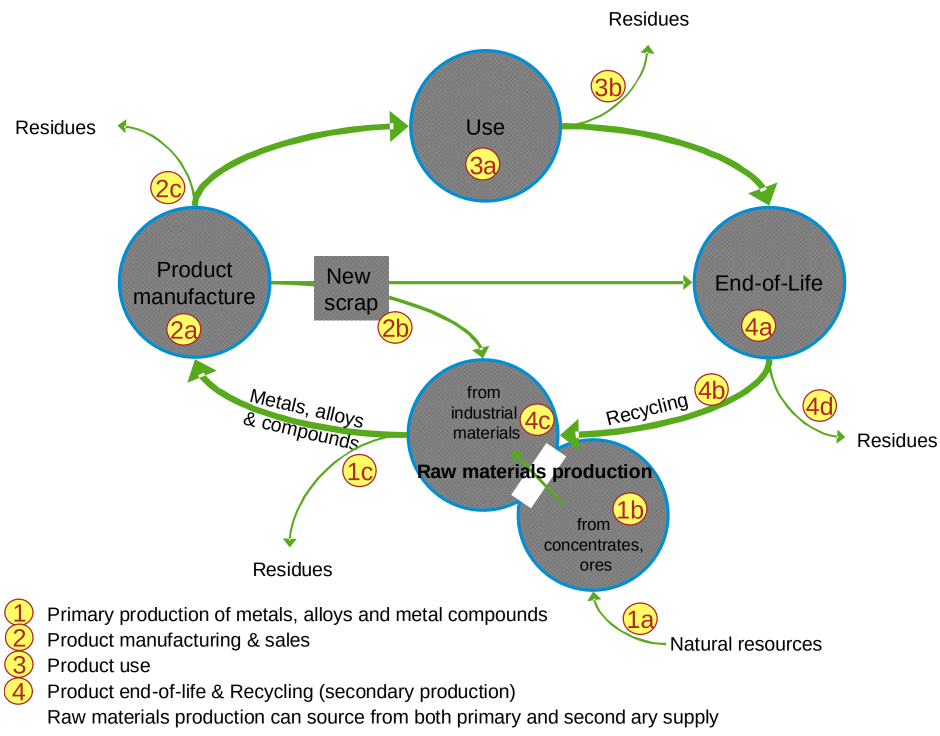
The Group recommends that the overall material efficiency of critical raw materials should be achieved by the combination of two fundamental measures:

- by minimising the raw material used to obtain a specific product function; this covers every step from smart production with metals and minerals savings to substitution of potentially critical raw materials by less critical ones;
- by minimising raw material losses into residues from where they cannot be economically-recovered.

The measures should be evaluated with regard to impacts on environmental and economic performance over the entire value chain.

As illustrated in figure 14 such residue streams occur in principle at every step in the life cycle.

Figure 14: Life cycle of products/metals with principal points of intervention to improve resource efficiency. Source: modified after C.E.M. Meskers, Coated Magnesium – designed for sustainability? Dissertation Delft, 2008.



ANNEXES

Annex I: Methodology for the quantitative assessment

The methodology used for the quantitative assessment is based on three main aggregated indicators or dimensions, i.e. the economic importance, the supply risk and the environmental country risk. The objective of this annex is to explain how these indicators have been calculated.

A1.1 Economic importance

It was decided by the Group to assess economic importance taking into account the end uses of a raw material and the value of the sectors into which they flow. The required data are therefore

1. The share of consumption of a material i (denoted A_{is}) in a given end-use sector, denoted s. For this exercise, a "megasector" approach was agreed upon by the Group. A megasector represents the value-added chain which will be affected by a shortage of the material i upstream. Every megasector is a grouping of related NACE sectors (see Annex II).
2. The economic importance of each sector that requires raw material i which is measured by its value-added, denoted Qs.

The economic importance of a raw material (EI_i), is then calculated as the weighted sum of the individual megasectors (expressed as gross value added), divided by the European gross domestic product (GDP):

$$EI_i = \frac{1}{GDP} \sum_s A_{is} Q_s$$

The necessary values for A_{is} were collected from publicly available information, from commercial reports and from information otherwise available to the members of the Group.

The economic importance of each megasector was estimated by adding the gross value added of each NACE code contained within each megasector.

For presentation purposes, the values for economic importance of each material were scaled to fit in the range from 0 to 10, with higher scores indicating higher economic importance.

A1.2 Supply risk

The estimation of the supply risk of a material i is based on the following elements:

1. an estimation of how stable the producing countries are, taking into consideration of the level of concentration of raw material producing countries,
2. the extent to which a raw material i may be substituted, and
3. the extent to which raw material needs are recycled.

A1.2.1 Stability/instability and level of concentration of producing countries

This is estimated by using the Worldwide Governance Indicators provided by the World Bank (http://info.worldbank.org/governance/wgi/sc_country.asp). This indicator is denoted here by WGI_c for the country c. The WGI_c was aggregated using a Herfindahl-Hirschmann-Index based on the share of the country c in the world production data, denoted S_{ic} :

$$HHI_{WGI} = \sum_c (S_{ic})^2 WGI_c$$

The values of WGI_c lie in the range from -2.5 to 2.5, with higher scores indicating better governance. In order to create an indicator resembling perceived risk, these values were scaled to the range 0 to 10 and their order inverted such that a higher score corresponds to poor governance and thus to a high risk. These scaled values were used in the calculations. The values of the modified Herfindahl-Hirschmann-Index lie in the range 0-100000 (because S_{ic} is not taken as a fraction but as the percent value). These values are then scaled to fit between 0 and 10.

A1.2.2 Substitutability

A supply risk on a raw material i, i.e. an impediment on access to the raw material i, - if happening -, will impact on the economy only if this raw material cannot be substituted or can only be substituted with difficulty or cost by another one. The possibility of substituting, called “substitutability” should thus be taken into account.

A first estimate of the possibility of substituting raw material i by a different raw material in each end-use was made "à dire d'experts" by Fraunhofer ISI. These estimates were then shared with experts from within the Group and, when the required expertise was not available, with experts from outside the Group. These experts revised the first estimates where appropriate and the revised figures were used in the calculations.

The estimated substitutability of each raw material in each end-use, denoted by s_{is} , took on the following possible values:

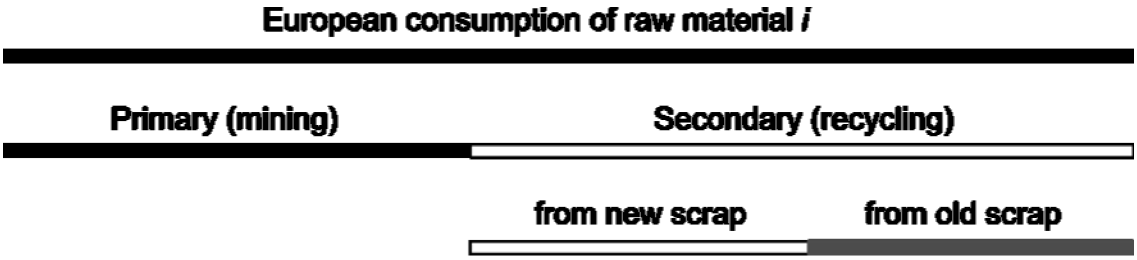
0.0	Easily and completely substitutable at no additional cost
0.3	Substitutable at low cost
0.7	Substitutable at high cost and/or loss of performance
1.0	Not substitutable

The overall substitutability index was calculated as a weighted average over the end-uses/sectors, as follows:

$$\mathrm{s}_i = \sum_s A_{is} \mathrm{s}_{is}$$

A1.2.3 Recycling

The calculations consider the extent to which European raw material needs are met by the Recycled Content rate (see sketch below).



The “new scrap” refers to scrap resulting from the processing of raw material from primary sources, whereas “old scrap” refers to raw material which has been recycled at the end of the life product from products in which it is incorporated.

The recycling rate used in this report, denoted by r_i, is the ratio of recycling from old scrap to European consumption, unless otherwise noted.

A1.2.4 Aggregation

The three elements described in A1.2.1 to A1.2.3 were put together into an assessment based on the concentration of production worldwide, whether or not this production is currently used to supply the EU:

$$SR_i = s_i (1 - r_i) HHI_{WGI}$$

The supply risk is increased if the producing countries are unstable and provide a high share in the world production, because the substitutatiblity is low ($s_i = \sum_s A_{is} s_{is}$ is high), and because the recycled rate is low (1 - r_i is high). It should be noted that it is implicitly assumed that there is no supply risk stemming from recycling (which is a simplification of the economic reality).

A.1.3 Environmental country risk

Similar to the calculations for supply risk, an environmental country index (EM_i) was adopted to reflect country risks arising from environmental reasons. This is based on the environmental performance index (http://epi.yale.edu/) of each country and is computed in a similar way to the supply risk, taking into account the concentration in country risks, the substitutability and the recycling rate.

$$EM_i = s_i (1 - r_i) HHI_{EPI}$$

The HHI_{EPI} is the direct analogue of the WBI-Version, as follows:

$$HHI_{EPI} = \sum_c (S_{ic})^2 EPI_c$$

As for the case of the supply risk, all values were appropriately scaled such that the values of EM_i lie between 0 and 10, with higher values indicating high environmental country risk.

Annex II: Megasectors

Introduction

The economic importance of each raw material has been assessed from the perspective of the value-added of those sectors using it as an input. A specific sectoral breakdown of the economy has been used in this assessment thus providing 17 broad sectors[23] referred to as "mega-sectors". These cover almost 90% of total value added for the EU's manufacturing sector in 2006[24]. They also cover use of raw materials in the energy and non-energy extractive sectors.

The mega-sectors used are tabulated below:

	Mega-sector	NACE Description	Value Added (Bn)	% of EU Manufacturing VA, 2006
	Manufacturing sectors included			
1	Construction Material	most of 26 incl 262 to 267; also 281	98,5	6%
2	Metals	27, 28 (exclud 281); 371	189,0	11%
3	Mechanical Equipment	29 (except 29.7)	181,5	11%
4	Electronics & ICT	all of 30, 32 and 33 & 31.40	123,1	7%
5	Electrical Equipment	all of 31 exc 31.40, 31.61, also 29.71	83,7	5%
6	Road Transport	all of 34; 29.31; 31.61, 35.4	156,3	9%
7	Aircraft, Shipbuilding, Trains	35.1, 35.2 and 35.3	48,2	3%
8	Other Final Consumer Goods (incl Jewellery)	36 and 286	69,5	4%
9	Food	151-158	154,4	9%
10	Beverages	159	34,0	2%
11	Paper	21	41,1	2%
12	Pharmaceuticals	244	70,5	4%
13	Chemicals	all of 24 except 244	116,4	7%
14	Rubber, Plastic & Glass	all of 25, 261, 268	100,4	6%
15	Refining	23	33,5	2%
			1.500,0	**88%**
	Manufacturing sectors not included (1)			
	Tobacco	16	8,2	0,5%
	Textiles & Clothes	17	64,4	4%
	Wood	20	37,1	2%
	Publishing & Printing	22	96,3	6%
			206,2	**12%**
	Total Sectors outlined above		**1.706,2**	**100%**
	Non-manufacturing mega-sector included			
16	Mining of Metal Ores	13	5,0	
17	Oil & Gas Extraction	11	59,2	

[23] Certain categories – such as food – are included for reasons of completeness. Where found to be irrelevant, any sector which is of marginal importance will be removed at the end of the process.
[24] This is the last year for which complete information was available.

<u>Rationale beyond Mega-sector Approach</u>

Value-Chain Approach to Economic Importance

The mega-sector approach is based on the concept of a 'value-added chain'. As each step of the value chain builds on previous steps, an upstream bottleneck in supply of raw material will threaten the whole value chain. It therefore seems thus logical to link the economic value of a chain to the economic importance of the raw materials used in this chain. Conceptually the mega-sectors are thus defined in order to aggregate all sectors or sub-sectors belonging to the same value chain. As raw materials go into different value chains with heterogeneous economic importance to the EU economy we can evaluate economic importance based on the raw material's contribution to different mega-sectors (e.g. importance of cobalt for 'Road Transport' and 'Electronics & ICT'), and not just its importance in first use (e.g. use of cobalt in batteries).

In mega-sectors such as Road Transport (No. 6) where we see a single product or at least a group of similar products sharing the same technological characteristics at the top of the value chain, we can assign the value added of the whole mega-sector meaningfully to the raw materials which go into these value chains.

Finally, in order to arrive at a consistent and coherent set of mega-sectors, it has been necessary to re-categorise certain Eurostat statistical data. For instance, the NACE metals categories - basic (NACE code 27), fabricated metals (code 28) and recycling of metals (code 37.1) – are combined into one mega-sector covering all metals.

Interpretation of link between Raw Material & the Value Added of a Mega-sector

As a particular raw material is not used by all subsectors within a given mega-sector, there is a risk that a raw material's importance to a mega-sector will be exaggerated. While we recognise that this is a valid concern, we have attempted to mitigate this problem by breaking down the manufacturing sector in a way which does not create bias in overestimation. As such, the mega-sectors are of similar size to one another. Finally, it should be borne in mind that this is a first attempt at defining the concept of a value-added chain. To increase the accuracy of such value-added chains, further in-depth work is required.

Measure Economic Importance limited to Manufacturing & Extraction Industries

The mega-sector approach mainly focuses its analysis on manufacturing.

Mega-sectors in Detail

Mega-sector	NACE component	Description
Construction Material (including fabricated metal used in construction)	most of 26 including 262 to 267; also 281	Ceramic tiles, bricks, concrete, cement, plaster, building stone, metal structures and parts of structures, builders' carpentry and joinery of metal, ceramic household and ornamental articles, ceramic sanitary fixtures, ceramic insulators and insulating fittings, refractory ceramic products.
Metals (Basic, Fabricated & Recycling)	27 (Basic Metals); 28 (Fabricated Metals) excluding 281 and 286; 371 (Recycling of metals)	Basic iron and steel and of ferro-alloys, tubes, cold drawing, cold rolling of narrow strip, cold forming or folding, wire drawing, basic precious and non-ferrous metals, casting of metals. Tanks, reservoirs and containers of metal, central heating radiators and boilers, forging, pressing, stamping and roll forming of metal; powder metallurgy, treatment and coating of metals, steel drums and similar containers, light metal packaging, wire products, fasteners, screw machine products, chain and springs. Recycling of metal waste and scrap
Mechanical Equipment	All 29 except agricultural tractors (road transport) and electrical household equipment	Mechanical power equipment (except aircraft, vehicle and cycle engines) including engines and turbines, pumps and compressors, taps and valves, bearings, gears, gearing and driving elements, furnaces and furnace burners, lifting and handling equipment , non-domestic cooling and ventilation equipment, machine-tools, machinery for metallurgy, mining, quarrying and construction, food, beverage and tobacco processing, textile, apparel and leather production, paper and paperboard production, agricultural and forestry machinery (except tractors) domestic appliances (non-electrical).
Electronics & ICT	all of 30, 32, 33 31.4 (batteries)	Office machinery and computers, accumulators, primary cells and primary batteries, electronic valves and tubes and other electronic components, television, radio transmitters and sound or video recording or reproducing equipment, telephony, medical and surgical equipment, instruments and appliances for measuring, checking, testing, navigating, industrial process control equipment, optical instruments, photographic equipment, watches and clocks.
Electrical Equipment	all of 31 exc 31.61, also some parts of 29.7 (electric domestic appliances.)	Electric motors, generators and transformers, electricity distribution and control apparatus, insulated wire and cable, lighting equipment and electric lamps. household electrical equipment,
Road Transport	all of 34; 29.31 (tractors); 31.61 (electrical equipment for vehicles), 35.4 (motorcycles/bicycles)	Agricultural tractors, electrical equipment for engines and vehicles, motor vehicles, bodies (coachwork) for motor vehicles, trailers and semi-trailers, parts and accessories for motor vehicles, motorcycles and bicycles

Aeronautics, Trains, Ships	35.1, 35.2 and 35.3	Ships and boats, railway, tramway locomotives, rolling stock ,aircraft and spacecraft
Other Final Consumer Goods (including Jewellery)	36, 286 (cutlery), 363-5 (Leisure)	furniture, cutlery, tools and general hardware, tools, locks and hinges, musical instruments, sports goods, games and toys, jewellery and related articles, coins, jewellery
Food	15.1-15.8	Self-explanatory
Beverages	15.9	Self-explanatory
Paper	21	Pulp, paper and paperboard, corrugated paper and paperboard and of containers of paper and paperboard, household and sanitary goods, paper stationary, wall paper, other
Pharmaceuticals	244	Self-explanatory
Chemicals	all of 24 except 244	Self-explanatory
Plastic, Glass & Rubber (non construction)	all of 25, 261, 262, 268	Rubber tyres and tubes, other rubber products plastic plates, sheets, tubes and profiles, plastic packing goods, flat glass, hollow glass, glass fibres, technical glassware, abrasive products
Refining	23	Petroleum, nuclear – information on Coke not available
Mining of Metal Ores	13	Iron, non-ferrous

Annex III: Statistical information

A3.1: Data required to estimate economic importance

Two sets of data are required to estimate economic importance as described in Annex I. These are (i) the share of net consumption of a raw material for each end use and (ii) the value of the sectors they go into. Point (ii) is described in detail in Annex II. The table below presents a listing of data sources used for point (i).

Material	Source	Remarks
Aluminum	European Aluminium Association	European data
Antimony	Roskill Information Services	Worldwide data
Barytes	The Barytes Association	Worldwide data
Bauxite	Hellenic Mining Enterprises	Worldwide data
Bentonite	Industrial Minerals Magazine and IMA Europe	European data
Beryllium	Eurometaux	European data
Borate	IMA Europe	European data
Chromium	Angerer et al. 2009	Worldwide data
Clays and kaolin	IMA Europe	European data
Cobalt	Eurometaux	European data
Copper	International Copper Association	European data
Diatomite	IMA Europe	European data
Feldspar	IMA Europe	European data
Fluorspar	Roskill Information Services	Worldwide data
Gallium	U.S. Geological Survey	US data
Germanium	U.S. Geological Survey	Worldwide data
Graphite	Ullmann's Encyclopedia of Chemical Technology	Worldwide data
Gypsum	U.S. Geological Survey	US data
Indium	Eurometaux	Worldwide data
Iron ore	European Confederation of Iron and Steel Industries	European data
Limestone	IMA Europe	European data
Lithium	Roskill Information Services	Woldwide data
Magnesite	Industry input	Worldwide data
Magnesium	Roskill Information Services	Worldwide data
Manganese	Roskill Information Services	Worldwide data
Molybdenum	Roskill Information Services	Worldwide data
Nickel	Roskill Information Services	Worldwide data
Niobium	Roskill Information Services	Worldwide data

Perlite	U.S. Geological Survey	US data
PGM	Roskill Information Services	Worldwide data
Rare earths	Roskill Information Services	Worldwide data
Rhenium	U.S. Geological Survey	US data
Silica sand	IMA Europe	European data
Silver	Fortis Investment Research	Worldwide data
Talc	IMA Europe	European data
Tantalum	RWI/ISI/BGR 2007	Worldwide data
Tellurium	Eurometaux	Worldwide data
Titanium	Roskill Information Services, U.S. Geological Survey, expert interview	Worldwide data
Tungsten	Roskill Information Services	Worldwide data
Vanadium	Roskill Information Services and U.S. Geological Survey	Worldwide data
Zinc	Roskill Information Services	Worldwide data

A3.2: Production data

Production data for the year 2008 were compiled form the following sources:

Material	Source(s)	Remarks
Aluminum	World Mining Data	
Antimony	World Mining Data	
Barytes	World Mining Data	
Bauxite	World Mining Data	
Bentonite	World Mining Data	
Beryllium	U.S. Geological Survey	
Borate	World Mining Data	
Chromium	World Mining Data	
Clays and kaolin	World Mining Data	Data for kaolin
Cobalt	World Mining Data	
Copper	World Mining Data	
Diatomite	World Mining Data	
Feldspar	World Mining Data	
Fluorspar	World Mining Data	
Gallium	World Mining Data	
Germanium	World Mining Data	
Graphite	World Mining Data	natural graphite

Gypsum	World Mining Data	data for gypsum and anhydrite
Indium	U.S. Geological Survey	
Iron ore	World Mining Data	
Limestone		
Lithium	World Mining Data	
Magnesite	World Mining Data	
Magnesium	U.S. Geological Survey	
Manganese	World Mining Data	
Molybdenum	World Mining Data	
Nickel	World Mining Data	
Niobium	U.S. Geological Survey	
Perlite	World Mining Data	
PGM	World Mining Data	data for platinum and palladium
Rare earths	World Mining Data	
Rhenium	U.S. Geological Survey	not all rhenium is extracted from the ores; data was adjusted to reflect what is actually processed
Silica sand	U.S. Geological Survey	
Silver	World Mining Data	
Talc	World Mining Data	
Tantalum	U.S. Geological Survey	with adjustments from the Federal Institute for Geosciences and Natural Resources (BGR)
Tellurium	World Mining Data	
Titanium	World Mining Data	
Tungsten	World Mining Data	
Vanadium	World Mining Data	
Zinc	World Mining Data	

A3.3: Trade data sources and codes

Trade data was obtained from the UN comtrade and the EUROSTAT ComExt databases. It was decided to assess trade as close to the raw material as possible. Trade of metal scrap is not included.

No conversion to metal content was necessary when there was no EU production and only one trade code was considered. In all other cases, the estimation of net imports is based on metal content where required. Exceptions to this rule were PGM and Rare Earths because convoluted trade statistics make it impossible to distinguish each single material in the groups.

Material	Code		Source
Aluminum	CN 7601 10 00	Unwrought aluminium, not alloyed	ComExt
Antimony	HS 261710	Antimony ores and concentrates	UN comtrade
Barytes	HS 2511	Natural barium sulphate (barytes)	UN comtrade
Bauxite	HS 2606	Aluminium ores and concentrates	UN comtrade
Bentonite	HS 250810	Bentonite	UN comtrade
	HS 250820	Decolorising earths and fuller's earth	
Beryllium	CN 8112 12 00	Beryllium umwrought; powders	ComExt
Borate	CN 2528 10 00	Natural sodium borates and concentrates thereof	ComExt
	CN 2528 90 00	Natural borates (excl. Na-Borates)	
	CN 2840 20 10	Refined borax	
	CN 2840 20 90	Borates	
Chromium	HS 2610	Chromium ores and concentrates	UN comtrade
Clays and kaolin	CN 2507 00 20	Kaolin	ComExt
	CN 2506 00 80	Kaolinic Clays	
	CN 2508 30 00	Fireclay	
	CN 2508 40 00	Product Clays	
Cobalt	HS 2605	Cobalt ores and concentrates	UN comtrade
Copper	HS 2603	Copper ores and concentrates	UN comtrade
Diatomite	HS 2512	Siliceous fossil meals	UN comtrade
Feldspar	HS 252910	Feldspar	UN comtrade
Fluorspar	HS 2529 21	Fluorspar, cont. by wt. 97%/less of calcium fluoride	UN comtrade
	HS 2529 22	Fluorspar, cont. by wt. >97% of calcium fluoride	
Gallium	CN 8112 92 89	Unwrought gallium; gallium powders	ComExt
Germanium	CN 8112 92 95	Germanium: Unwrought; waste and scrap; powders	ComExt
Graphite	HS 2504	Natural graphite	UN comtrade
Gypsum	HS 2520 10	Gypsum; anhydrite	UN comtrade
Indium	CN 8112 92 81	Unwrought indium; indium powders	ComExt

Iron ore	HS 2601 11	Iron ores & concs. (excl. roasted iron pyrites), non-agglomerated	UN comtrade
	HS 2601 12	Iron ores & concs. (excl. roasted iron pyrites), agglomerated	
Limestone	CN 2521	Limestone flux, limestone and other calcareous stone, of a kind used for the manufacture of lime and cement	ComExt
	CN 2509	Chalk	
	CN 251741	Marble granulate and powders	
Lithium	HS 2825 20	Lithium oxide and hydroxide	UN comtrade
	HS 2836 91	Lithium carbonate	
Magnesite	HS 2519 10	Natural magnesium carbonate (magnesite)	UN comtrade
Magnesium	CN 8104 19 00	Unwrought Magnesium, < 99.8% Mg	ComExt
	CN 8104 11 00	Unwrought Magnesium, >= 99.8% Mg	
Manganese	HS 2602	Manganese ores and concentrates	UN comtrade
Molybdenum	HS 2613	Molybdenum ores and concentrates	UN comtrade
Nickel	HS 2604	Nickel ores and concentrates	UN comtrade
Niobium	CN 7202 93 00	Ferro-niobium	ComExt
Perlite	CN 2530 10 10	Perlite, unexpanded	ComExt
PGM	HS 7110 11	Platinum, unwrought/in powder form	UN comtrade
	HS 7110 19	Platinum, in semi-manufactured forms	
	HS 7110 21	Palladium, unwrought/in powder form	
	HS 711029	Palladium, in semi-manufactured forms	
	HS 7110 31	Rhodium, unwrought or in powder form	
	HS 7110 39	Rhodium, other	
	HS 7110 41	Iridium, Osmium, Ruthenium, unwrought or in powder form	
	HS 7110 49	Iridium, Osmium, Ruthenium, other	
Rare earths	HS 2805 30	Rare-earth metals, scandium & yttrium, whether or not intermixed/interalloyed	UN comtrade
	HS 2846 10	Cerium compounds	
	HS 2846 90	Compounds, inorganic/organic, of rare-earth metals/yttrium/scandium/mixtures	
Rhenium			
Silica sand	CN 2505 10 00	Silica sands and quarz sands	ComExt
Silver	HS 2616 10	Silver ores and concentrates	UN comtrade
Talc	HS 2526	Natural steatite, whether or not roughly trimmed	UN comtrade

Tantalum	CN 8103 20 00	Unwrought tantalum	
Tellurium	CN 2804 50 90	Tellurium	ComExt
Titanium	HS 2614	Titanium ores and concentrates	UN comtrade
Tungsten	HS 2611	Tungsten ores and concentrates	UN comtrade
Vanadium	CN 2615 90 90	Vanadium ores and concentrates	ComExt
Zinc	HS 2608	Zinc ores and concentrates	UN comtrade

A3.4: Country-based indices

The political and economic stability of producing countries was measured by making use of the Worldwide Governance Indicator (WGI) published regularly by the World Bank[25] and their environmental performance by making use of the "Environmental Performance Index (EPI)[26]. In practice, these indexes were scaled to fit in the range from 0 to 10.

25 http://info.worldbank.org/governance/wgi/sc_country.asp

26 http://epi.yale.edu/

Country	WGI	Scaled
ALBANIA	-0,4	5,8
ALGERIA	-0,7	6,4
ANGOLA	-1,1	7,2
ARGENTINA	-0,2	5,4
ARMENIA	-0,3	5,7
AUSTRALIA	1,6	1,8
AUSTRIA	1,6	1,8
AZERBAIJAN	-0,8	6,6
BAHAMAS	1,1	2,8
BAHRAIN	0,2	4,6
BANGLADESH	-0,9	6,8
BARBADOS	1,1	2,8
BELGIUM	1,4	2,3
BELIZE	0,0	4,9
BENIN	-0,3	5,5
BOLIVIA	-0,7	6,3
BOSNIA-HERZEGOVINA	-0,4	5,7
BOTSWANA	0,7	3,7
BRAZIL	-0,1	5,1
BULGARIA	0,2	4,6
BURKINA FASO	-0,4	5,9
BURUNDI	-1,2	7,3
CAMEROON	-0,8	6,7
CANADA	1,6	1,8
C. AFRICAN REP.	-1,4	7,7
CHAD	-1,4	7,8
CHILE	1,1	2,8
CHINA	-0,5	6,1
COLOMBIA	-0,4	5,8
Congo, Dem. Rep.	-1,8	8,6
CONGO	-1,2	7,3
COSTA RICA	0,5	4,0
COTE D'IVOIRE	-1,4	7,9
CROATIA	0,3	4,4

CYPRUS	1,0	3,1
CZECH REPUBLIC	0,9	3,3
DENMARK	1,8	1,4
DOMINICAN REP.	-0,2	5,5
ECUADOR	-0,9	6,7
EGYPT	-0,6	6,3
EL SALVADOR	-0,1	5,2
ESTONIA	1,0	2,9
ETHIOPIA	-0,9	6,8
FIJI	-0,3	5,5
FINLAND	1,9	1,2
FRANCE	1,2	2,6
GABON	-0,6	6,2
GEORGIA	-0,4	5,8
GERMANY	1,5	2,0
GHANA	0,1	4,8
GREECE	0,7	3,7
GUATEMALA	-0,6	6,1
GUINEA-BISSAU	-0,9	6,8
GUYANA	-0,4	5,8
HAITI	-1,3	7,5
HONDURAS	-0,5	6,1
HONG KONG	1,5	2,1
HUNGARY	0,9	3,2
ICELAND	1,9	1,2
INDIA	-0,1	5,2
INDONESIA	-0,6	6,2
IRAN	-1,1	7,1
IRELAND	1,6	1,9
ISRAEL	0,6	3,8
ITALY	0,6	3,9
JAMAICA	0,0	5,1
JAPAN	1,3	2,5
JORDAN	0,0	5,0
KAZAKHSTAN	-0,6	6,2
KENYA	-0,6	6,2
KOREA, SOUTH	0,7	3,7

KUWAIT	0,4	4,2
KYRGYZSTAN	-0,9	6,9
LATVIA	0,7	3,6
LESOTHO	-0,2	5,4
LITHUANIA	0,7	3,6
LUXEMBOURG	1,7	1,5
MACEDONIA	-0,3	5,5
MADAGASCAR	-0,2	5,5
MALAWI	-0,5	6,0
MALAYSIA	0,4	4,2
MALI	-0,3	5,6
MALTA	1,2	2,5
MAURITANIA	-0,5	6,1
MAURITIUS	0,6	3,8
MEXICO	-0,1	5,2
MOLDOVA	-0,6	6,2
MONGOLIA	-0,1	5,3
MONTENEGRO	-0,4	5,7
MOROCCO	-0,2	5,5
MOZAMBIQUE	-0,3	5,6
MYANMAR	-1,7	8,3
NAMIBIA	0,3	4,4
NEPAL	-1,0	7,0
NETHERLANDS	1,6	1,8
NEW ZEALAND	1,8	1,5
NICARAGUA	-0,6	6,1
NIGER	-0,7	6,3
NIGERIA	-1,1	7,3
NORWAY	1,7	1,6
OMAN	0,4	4,2
PAKISTAN	-0,9	6,8
PANAMA	0,1	4,8
PAPUA NEW GUINEA	-0,7	6,4
PARAGUAY	-0,8	6,5
PERU	-0,4	5,7
PHILIPPINES	-0,5	5,9
POLAND	0,5	4,1

PORTUGAL	1,0	3,0
ROMANIA	0,1	4,7
RUSSIA	-0,7	6,5
RWANDA	-0,6	6,2
SENEGAL	-0,2	5,5
SERBIA	-0,3	5,7
SIERRA LEONE	-0,9	6,8
SINGAPORE	1,5	2,1
SLOVAKIA	0,7	3,5
SLOVENIA	1,0	3,1
SOUTH AFRICA	0,5	4,1
SPAIN	0,9	3,2
SRI LANKA	-0,4	5,7
SWEDEN	1,7	1,6
SWITZERLAND	1,8	1,4
SYRIA	-1,0	7,0
TAIWAN	0,8	3,4
TANZANIA	-0,3	5,6
THAILAND	-0,2	5,4
TOGO	-1,1	7,3
TRINIDAD & TOBAGO	0,2	4,6
TUNISIA	0,0	4,9
TURKEY	0,0	5,1
UGANDA	-0,6	6,2
UKRAINE	-0,4	5,8
UNITED ARAB EMIRATES	0,5	4,1
UNITED KINGDOM	1,6	1,9
UNITED STATES	1,3	2,5
URUGUAY	0,6	3,8
VENEZUELA	-1,0	7,0
VIETNAM	-0,5	6,1
ZAMBIA	-0,5	6,0
ZIMBABWE	-1,5	8,0

Country	EPI	Scaled
Albania	71,4	2,9
Algeria	67,4	3,3
Angola	36,3	6,4
Antigua & Barbuda	69,8	3,0
Argentina	61,0	3,9
Armenia	60,4	4,0
Australia	65,7	3,4
Austria	78,1	2,2
Azerbaijan	59,1	4,1
Bahrain	42,0	5,8
Bangladesh	44,0	5,6
Belarus	65,4	3,5
Belgium	58,1	4,2
Belize	69,9	3,0
Benin	39,6	6,0
Bhutan	68,0	3,2
Bolivia	44,3	5,6
Bosnia & Herzigovina	55,9	4,4
Botswana	41,3	5,9
Brazil	63,4	3,7
Brunei	60,8	3,9
Bulgaria	62,5	3,8
Burkina Faso	47,3	5,3
Burundi	43,9	5,6
Cambodia	41,7	5,8
Cameroon	44,6	5,5
Canada	66,4	3,4
Central African Rep.	33,3	6,7
Chad	40,8	5,9
Chile	73,3	2,7
China	49,0	5,1
Colombia	76,8	2,3
Congo	54,0	4,6
Costa Rica	86,4	1,4
Côte d'Ivoire	54,3	4,6

Croatia	68,7	3,1
Cuba	78,1	2,2
Cyprus	56,3	4,4
Czech Republic	71,6	2,8
Dem. Rep. Congo	51,6	4,8
Denmark	69,2	3,1
Djibouti	60,5	4,0
Dominican Republic	68,4	3,2
Ecuador	69,3	3,1
Egypt	62,0	3,8
El Salvador	69,1	3,1
Equatorial Guinea	41,9	5,8
Eritrea	54,6	4,5
Estonia	63,8	3,6
Ethiopia	43,1	5,7
Fiji	65,9	3,4
Finland	74,7	2,5
France	78,2	2,2
Gabon	56,4	4,4
Gambia	50,3	5,0
Georgia	63,6	3,6
Germany	73,2	2,7
Ghana	51,3	4,9
Greece	60,9	3,9
Guatemala	54,0	4,6
Guinea	44,4	5,6
Guinea-Bissau	44,7	5,5
Guyana	59,2	4,1
Haiti	39,5	6,1
Honduras	49,9	5,0
Hungary	69,1	3,1
Iceland	93,5	0,7
India	48,3	5,2
Indonesia	44,6	5,5
Iran	60,0	4,0
Iraq	41,0	5,9
Ireland	67,1	3,3

Israel	62,4	3,8
Italy	73,1	2,7
Jamaica	58,0	4,2
Japan	72,5	2,8
Jordan	56,1	4,4
Kazakhstan	57,3	4,3
Kenya	51,4	4,9
Kuwait	51,1	4,9
Kyrgyzstan	59,7	4,0
Laos	59,6	4,0
Latvia	72,5	2,8
Lebanon	57,9	4,2
Libya	50,1	5,0
Lithuania	68,3	3,2
Luxembourg	67,8	3,2
Macedonia	60,6	3,9
Madagascar	49,2	5,1
Malawi	51,4	4,9
Malaysia	65,0	3,5
Maldives	65,9	3,4
Mali	39,4	6,1
Malta	76,3	2,4
Mauritania	33,7	6,6
Mauritius	80,6	1,9
Mexico	67,3	3,3
Moldova	58,8	4,1
Mongolia	42,8	5,7
Morocco	65,6	3,4
Mozambique	51,2	4,9
Myanmar	51,3	4,9
Namibia	59,3	4,1
Nepal	68,2	3,2
Netherlands	66,4	3,4
New Zealand	73,4	2,7
Nicaragua	57,1	4,3
Niger	37,6	6,2
Nigeria	40,2	6,0

North Korea	41,8	5,8
Norway	81,1	1,9
Oman	45,9	5,4
Pakistan	48,0	5,2
Panama	71,4	2,9
Papua New Guinea	44,3	5,6
Paraguay	63,5	3,7
Peru	69,3	3,1
Philippines	65,7	3,4
Poland	63,1	3,7
Portugal	73,0	2,7
Qatar	48,9	5,1
Romania	67,0	3,3
Russia	61,2	3,9
Rwanda	44,6	5,5
Sao Tome & Principe	57,3	4,3
Saudi Arabia	55,3	4,5
Senegal	42,3	5,8
Serbia & Montenegro	69,4	3,1
Sierra Leone	32,1	6,8
Singapore	69,6	3,0
Slovakia	74,5	2,6
Slovenia	65,0	3,5
Solomon Islands	51,1	4,9
South Africa	50,8	4,9
South Korea	57,0	4,3
Spain	70,6	2,9
Sri Lanka	63,7	3,6
Sudan	47,1	5,3
Suriname	68,2	3,2
Swaziland	54,4	4,6
Sweden	86,0	1,4
Switzerland	89,1	1,1
Syria	64,6	3,5
Tajikistan	51,3	4,9
Tanzania	47,9	5,2
Thailand	62,2	3,8

Togo	36,4	6,4
Trinidad and Tobago	54,2	4,6
Tunisia	60,6	3,9
Turkey	60,4	4,0
Turkmenistan	38,4	6,2
Uganda	49,8	5,0
Ukraine	58,2	4,2
United Arab Emirates	40,7	5,9
United Kingdom	74,2	2,6
United States	63,5	3,7
Uruguay	59,1	4,1
Uzbekistan	42,3	5,8
Venezuela	62,9	3,7
Viet Nam	59,0	4,1
Yemen	48,3	5,2
Zambia	47,0	5,3
Zimbabwe	47,8	5,2

A3.5: Main producers and import sources to the EU

Raw material	Main producing countries	Main EU import sources	Import dependence (2006)
Aluminium	2008: China 34% Russia 9% Canada 8%	2006: Russia 27% Mozambique 20% Brazil 11% Norway 11%	47%
Bauxite	2008: Australia 30% China 17% Brazil 11%	2006: Guinea 55% Australia 19% Brazil 10%	95%
Antimony	2009: China 91% Bolivia 2% Russia 2% South Africa 2%	2007: Bolivia 77% China 15% Peru 6%	100%
Barytes	2009: China 55% India 15% USA 7%	2007: China 63% Morocco 31% Turkey 5%	57%
Bentonite	2008: USA 42% Greece 8% Turkey 8%	2006: Turkey 28% USA 27% India 20%	15%
Beryllium	2009: USA 85% China 14% Mozambique 1%	Trading partners vary from year to year and include USA, Canada, China and Brazil.	100%
Borate	2008: Turkey 46% Argentina 18% Chile 13%	2006: Turkey 71% USA 18% Chile 4%	100%
Chromium	2009: South Africa 41% India 17% Kazakhstan 15%	2006: South Africa 79% Turkey 16% Albania 2%	46%

Clays	2009: USA 27% Uzbekistan 10% Germany 8%	2007: Ukraine 65% Brazil 17% USA 15%	23%
Cobalt	2008: Dem. Rep. Congo 41% Canada 11% Zambia 9%	2007: Dem. Rep. Congo 71% Russia 19% Tanzania 5%	100%
Copper	2008: Chile 35% USA 9% Peru 8%	2007: Chile 33% Indonesia 19% Peru 17%	54%
Diatomite	2008: USA 35% China 20% Denmark 10%	2007: USA 39% Turkey 33% Mexico 24%	25%
Feldspar	2008: Turkey 30% Italy 22% China 9%	2007: Turkey 98% Morocco 1% Norway 1%	47%
Fluorspar	2009: China 59% Mexico 18% Mongolia 6%	2007: China 27% South Africa 25% Mexico 24%	69%
Gallium	N.A.	Trading partners vary from year to year and include USA and Russia.	Large changes in the statistics for different years
Germanium	2009: China 72% Russia 4% USA 3%	2007: China 72% USA 19% Hong Kong 7%	100%
Graphite	2008: China 72% India 13% Brazil 7%	2007: China 75% Brazil 8% Madagascar 3% Canada 3%	95%
Gypsum and anhydrite	2009: China 28%	2007: Morocco 57%	1%

	Spain 8%	Ukraine 19%	
	Iran 8%	Bosnia Herzegovina 14%	
Indium	2008:	2006:	100%
	China 58%	China 81%	
	Japan 11%	Hong Kong 4%	
	Korea 9%	USA 4%	
	Canada 9%	Singapore 4%	
Iron	2008:	2009:	85%
	China 35%	Brazil 51%	
	Brazil 18%	Russia 10%	
	Australia 15%	Ukraine 9%	
Limestone	2009:	2006:	56%
	China 67%	Norway 92%	
	USA 5%	Turkey 8%	
	Japan 3%		
Lithium	2009:	2007:	74%
	Chile 42%	Chile 64%	
	Australia 25%	USA 17%	
	China 13%	China 16%	
Magnesite	2005:	2006:	2%
	China 53%	Turkey 70%	
	Russia 12%	China 18%	
	Turkey 8%	Brazil 11%	
Magnesium	2009:	2006:	100%
	China 56%	China 82%	
	Turkey 12%	Israel 9%	
	Russia 7%	Norway 3%	
		Russia 3%	
Manganese	2009:	2007:	91%
	China 25%	Brazil 39%	
	Australia 17%	South Africa 33%	
	South Africa 14%	Gabon 26%	
Molybdenum	2009:	2006:	100%
	China 38%	USA 47%	
	USA 25%	Chile 32%	
	Chile 16%	China 10%	
Nickel	2008:	2006:	55%
	Russia 18%	Australia 90%	
	Canada 17%	Norway 4%	

	Indonesia 12%	Turkey 4%	
Niobium	2009: Brazil 92% Canada 7%	2006: Brazil 84% Canada 16%	100%
Perlite	2008: Greece 29% USA 24% Turkey 15%	2006: Turkey 98%	13%
PGM	Only Pt, 2009: South Africa 79% Russia 11% Zimbabwe 3%	2006: South Africa 60% Russia 32% Norway 4%	100%
Rare Earth Elements	2009: China 97% India 2% Brazil 1%	2007: China 90% Russia 9% Kazakhstan 1%	100%
Rhenium	2008: Chile 49% USA 14% Kazakhstan 14%	Trading partners vary from year to year and include Taiwan, USA, Malaysia and Canada	100%
Silica sand	2006: USA 23% Italy 11% Germany 6%	2006: Egypt 57% Tunisia 14% Morocco 12%	14%
Silver	2008: Peru 17% Mexico 15% China 13%	Trading partners vary from year to year and include Argentina, South Africa, Chile, USA and Indonesia.	45%
Talc	2008: China 29% Korea, Rep. of 11% USA 9%	2006: China 60% Egypt 20% USA 7% Dem. People's Rep. of Korea, North 7%	11%
Tantalum	2009: Australia 48% Brazil 16% Rwanda 9% Dem. Rep. Congo	2007: China 46% Japan 40% Kazakhstan14%	100%

	9%		
Tellurium	2006: Canada 59% Peru 26% Japan 16%	Trading partners vary from year to year and include Canada, China, Morocco, South Korea and Norway	100%
Titanium	2009: Australia 25% Canada 19% South Africa 17%	2007: Canada 28% Norway 26% Australia 22%	100%
Tungsten	2008: China 78% Russia 5% Canada 4%	2006: Russia 76% Bolivia 7% Rwanda 13%	73%
Vanadium	2008: China 36% South Africa 36% Russia 26%	2006: South Korea 90% Japan 7% Venezuela 3%	100%
Zinc	2008: China 28% Peru 14% Australia 13%	2007: Peru 33% Australia 27% USA 16%	64%

A3.6: Recycling rates

The recycling rate used in this exercise was the recycled content considering old scrap recycling only. Most data was extracted from the upcoming UNEP report "The Recycling of Metals: A Status Report" from the Global Metal Flows Group to the International Panel for Sustainable Resource Management, chaired by Mr. T. Graedel. Other sources were as follows:

Aluminum	European Aluminium Association
Barytes	U.S. Geological Survey
Bauxite	U.S. Geological Survey
Borates	U.S. Geological Survey
Clays	U.S. Geological Survey
Copper	UNEP (upcoming), The Recycling of Metals: A Status Report, Report of the Global Metal Flows Group to the International Panel for Sustainable Resource Management. Graedel T. et al.; International Copper Study Group
Diatomite	U.S. Geological Survey
Gypsum	WG input
Lithium	U.S. Geological Survey
Silica sand	estimated from the average recycling rate for glass in Europe (62%) and the percent of use of silica sand in glass

No comparable information was available for bentonite, feldspar, fluorspar, graphite, limestone, magnesite, perlite, talc, tellurium and vanadium. For all these, it was assumed that no recycling takes place in the sense described above.

Annex IV: List of members of the Group

Chair

CATINAT Michel, Chairman of the Group, European Commission, Enterprise and Industry DG

Members - *in alphabetical order* –

ANCIAUX Paul, European Commission, Enterprise and Industry DG

BACKMAN Carl-Magnus Dr, Geological Survey of Sweden

BOSMANS Werner, European Commission, Environment DG

BUCHHOLZ Peter Dr, BGR *(Federal Institute for Geosciences and natural resources)*, Germany[27]

FERRI Antonin, European Commission, Trade DG

GERNUKS Marko Dr, Volkswagen

GUNN Andrew, British Geological Survey

HAGELÜKEN Christian Dr, Umicore

HEBESTREIT Corina Dr, Euromines

HOCQUARD Christian, BRGM *(French geological survey)*, France[28]

HORNINGER Sandra, Plansee

JONES Monique, Eurométaux

KAVINA Pavel Dr, Ministry of Trade and industry, Czech Republic[29]

KERTESZ Botond, Colas-Északk• Mining Ltd, Hungarian Mining Association, Euromines

KOSKINEN Kaisa-Reeta, Nokia

LAWLOR Niall, European Commission, Enterprise and Industry DG

MAGER Diethard Dr, Ministry of Economy and Technology, Germany

MARKLUND Ulf, Boliden

MOLL Stephan, European Commission, Eurostat

MORLIERE Adeline, Ministry of Ecology, Energy and Sustainable Development, France

REIMANN Matthias Dr, Knauf Gips KG

RELLER Armin Prof, University of Augsburg

WEBER Leopold Dr, Ministry of Economy, Austria[30]

WYART-REMY Michelle Dr, Industrial Minerals Association Europe

Some NGOs invited have not attended the meetings of the Group.

Invited experts

FRANCO AMENDES Alfredo, Ministry of Economy, General Directorate Energy and Geology, Portugal

GANDENBERGER Carsten Dr, Fraunhofer Institute for Systems and Innovation Research (consultant)

LE GUERN Yannick, Bio Intelligence Service (consultant)

MARSCHEIDER-WEIDEMANN Frank Dr, Fraunhofer Institute for Systems and Innovation Research (consultant)

TERCERO ESPINOZA Luis Dr, Fraunhofer Institute for Systems and Innovation Research (consultant)

[27] Mr Buchholz was replaced in some meetings by Dr Heinrike Sievers of BGR.
[28] Mr Hocquard was replaced at a certain stage by Mr Bruno Martel-Jantin of BRGM.
[29] Dr Kavina was replaced in some meetings by Mr Rosecky of the same Ministry.

[30] Dr Weber alternated with his colleague Michael Schatz of the same Ministry.