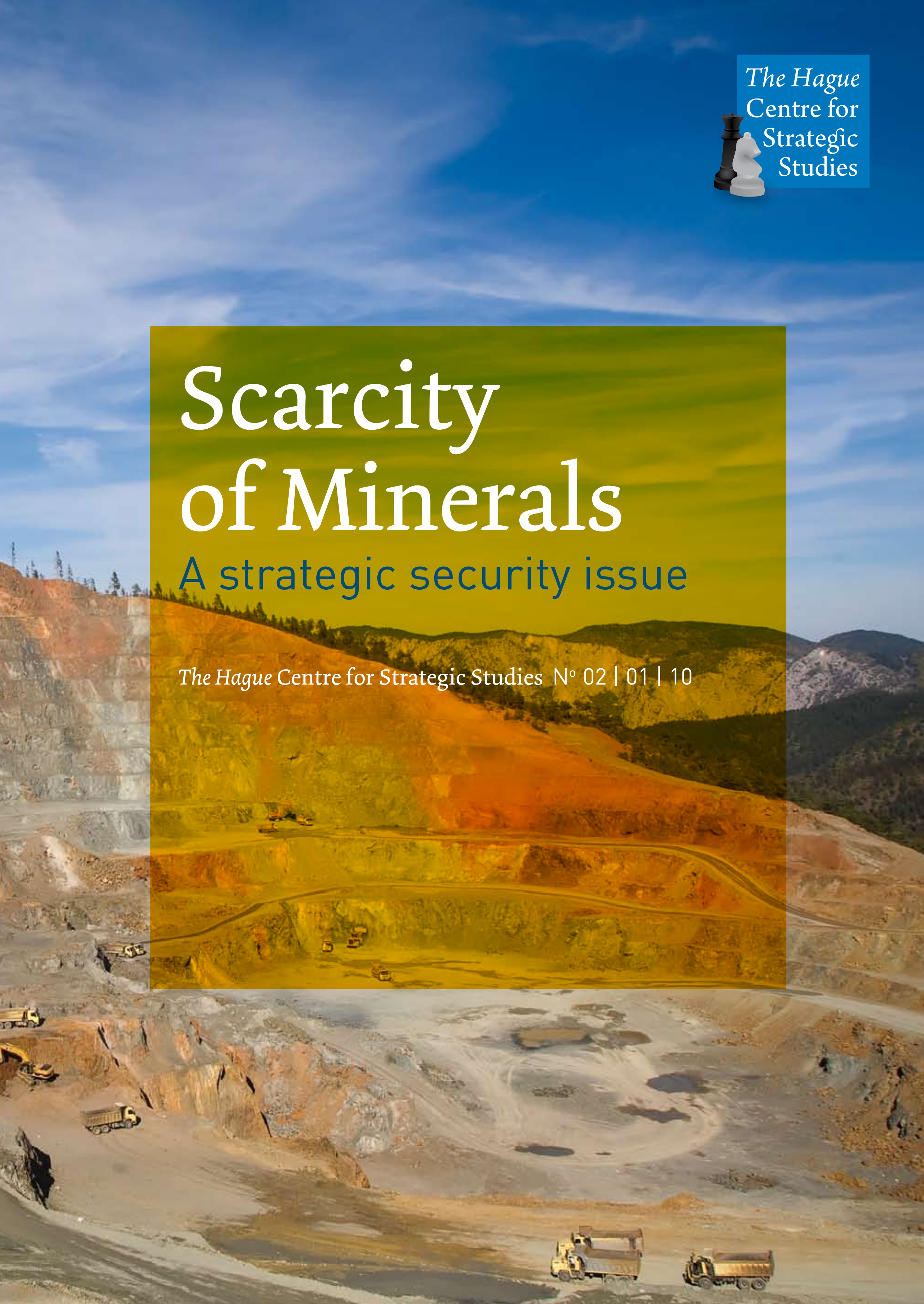

The Hague Centre for Strategic Studies

Scarcity of Minerals

A strategic security issue

The Hague Centre for Strategic Studies N° 02 | 01 | 10

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Executive Summary

What do we know about the quantity and availability of minerals that are used in industrial production and that are essential for economic growth, now and in the future? China is securing its supply of not only oil and gas, but also of minerals, through multi-billion dollar deals with countries worldwide. For some African countries, Chinese investments in mining and mineral extraction are the biggest foreign investments in the country. Among the primary products purchased by China from Latin America are iron and copper. In addition, China has recently announced a renewed tightening of export restriction on so-called 'rare earth elements'; naturally occurring materials that are vital for the production of green technology (e.g. batteries for hybrid cars), smartphones, and precision weapons. Chinese investment flurry around the globe and the country's export quotas seem to suggest that some minerals may soon be in short supply. Is this so? The Organisation for Economic Co-operation and Development (OECD) estimates global demand for minerals to double over the next 25 years. Will supply be able to keep up?

This report looks at whether minerals may be scarce in the near future and the geopolitical and security implications this may have. Will states use access to or possession of minerals as a strategic resource? Will relations between states that have access to minerals and those that don't change due to scarcity? Are future wars about minerals rather than oil, territory or water?

Our research indicates that mineral scarcity is not a matter of simply asking 'how much is still left?' or 'when will this or that mineral run out?'. In reality, only a very small percentage (0,01-0,001%) of existing mineral resources in the earth' crust is extracted. The bulk of available mineral deposits is not (yet) exploited, due to technological or economic limitations, or because it would require too much energy to do so. In fact, the global reserves of minerals that can be exploited fluctuate but have remained fairly constant over time. Global mineral reserves today are at roughly the same level as one decade ago, even though demand and production have grown. But results from the past are no guarantee for the future. The question is whether, given the growing demand, this trend will continue.

While scarcity is a fact of life, mineral scarcity in the absolute sense does not exist. Scarcity of minerals in the 20th century has actually decreased, mainly because mineral reserves shrink and grow in response to price shifts or technological advances. Recycling of materials and substitutes also influence the availability of minerals. Thus, mineral reserves are not a physical but an economic variable. Scarcity of minerals is not about depleting existing stocks but about the amount of extraction that becomes profitable under existing market conditions. Scarcity of minerals is therefore not a linear equation of quantity and time, but a relative economic concept. The basic fallacy of the scarcity debate is the assumption that mineral reserves are static. In reality, they are dynamic.

Stating that mineral reserves are dynamic is not the same as to state that mineral scarcity may not occur in the future. It might. But whether it will or not does not only depend on the known quantity of mineral reserves but also on a number of interrelated factors, including mining technology, demand and production, supply, the price of energy and the price of minerals.

Known mineral reserves are limited. It is unclear to what extent future reserves are economically or technically extractable. In terms of mining, the 'low-hanging' fruits have been picked and it is fair to assume that mining will have to move to more remote and hostile environments. Developments in mining technology are slow. Demand is rising due to the combined effect of new technological applications and economic growth. Due to long lead-times in the mining and recycling industry, supply is inelastic. This means that even steep price increases only slowly translate into an expansion of output. Likewise, demand is inelastic. Increase in price only slowly results in decreased demand, as substitutes might not be available or require extensive research. Energy price shocks will lead to increased production costs of minerals, triggering 'mineral price shocks.'

The control of the supply of scarce minerals is in the hands of a few countries and companies. Faced with the prospect of increasing demand and tightening supply of minerals used in critical applications, access to scarce minerals and stockpiles are increasingly framed as issues of vital interest or national security. Some countries are pursuing mineral policies aimed at preventing or mitigating mineral scarcity. The US, China and Japan pursue mineral policies that secure supplies, assuming growing scarcity and economic disruption when supplies dwindle. These policies may create their own dynamic, distorting free market dynamics and tightening supply. Mineral scarcity is no longer a trade-issue but an issue of strategic interest.

Scarcity of minerals is an issue that needs urgent attention of policy-makers. It is a complex phenomenon and subject to high degrees of uncertainty. Rather than short-term action based on fears of depleting known mineral reserves, prudent, long-term approaches are needed to mitigate mineral scarcity and prevent its most harmful effects.

Compared to debates on water and energy scarcity, the debate on mineral scarcity is just beginning. Many questions remain that need to be addressed to gain a better understanding of mineral scarcity.

The key findings of our research are as follows:

Supply and demand

- While prices have fallen for over two decades after spiking sharply in the 1980's, this trend has reversed over the past couple of years. Real prices have more than doubled since 2002 and have reached a level they haven't seen since the second oil shock nearly three decades ago.
- Until 2000, global output of minerals on average had increased fivefold since 1950. Until 2007, production again grew by 17% in the case of precious metals, by 33% percent in the case of mass consumables, and by 46% percent in the case of doping agents.
- Continued industrialization of the developing world will lead to rising global demand for scarce minerals. According to the OECD, global demand for minerals is expected to double over the next 25 years. It is also equally sure that emerging economies will consume a growing share of global mineral output and increasingly compete with Western countries over access to scarce mineral reserves. Demand for metals from China has already increased 17% annually over the past five years, and accounts for more than 70% of the global demand growth for several metals such as aluminium, copper or zinc. Emerging economies are also starting to contribute significantly to the output and consumption of high-tech products.

- The growth patterns and the volume for the different groups of minerals vary. While mass consumables are mined in volumes of tens of millions of tons per year, only a few million tons of doping agents and a just few thousand tons of precious metals are supplied to global mineral markets annually.
- The growth of production of minerals has been uneven. For example, the growth of platinum group metals has significantly outpaced the expansion of gold production within the precious metals category.
- Crude oil prices are a relatively suitable approximation of the development of the price of global energy prices and they matter to mineral prices as energy is a key input in mineral production because mining, refining, and transportation of minerals is are extremely energy intensive processes. The development of mineral prices is remarkably in sync with the evolution of the crude oil prices. The relationship between energy and mineral prices is an issue with potentially important ramifications for the scarcity debate.

Geography

- The expansion of global mineral output over the past one and a half centuries has led to a geographic shift in total mineral production. Six resource rich developing countries provided a quarter of world production. The trend of production away from Western countries towards developing countries (China in particular) is continuing into the new millennium.
- This shift reflects two basic trends. First, the rapid industrialization of many parts of the world outside of the US and Western Europe over the 20th century has made industrial mining a global phenomenon. Second, the widespread depletion of economically competitive reserves in those countries that industrialized early on has pushed exploration and mining away from Western Europe and the US towards areas that were previously untouched.
- The global distribution of mineral deposits or reserves that are economically exploitable with current technologies is highly asymmetric as well. For most elements, global reserves are located in a handful of countries.
- There are some important factors that create serious concerns about to what extent mineral production can be expanded at the same rates as in the past. Two key factors are the increasing *geological* and *geographical distance* to minerals. Past mining has concentrated on picking the 'low-hanging fruit' and depleted those resources that were of the highest quality, easiest to extract and closest to consumers. Future mining will face an increasing geological distance. This means mining deposits of lower ore grade, which are found in

deeper and less accessible layers in the planet's crust. Deposits are to be found at greater geographic distance from centres of consumption and in less accessible environments (e.g. offshore). Both trends are likely to make mining more energy intensive; and coupled with worries about high energy prices over the next decades, this might lead to much higher production costs.

Country policies

A number of conclusions can be drawn as to how individual countries view the mineral environment. Two trends can be discerned.

- Mineral supply is primarily considered a technological issue. The majority of mineral policies, with the exception of the United States, China and Japan, do not focus on the issue of scarcity and security of supply. Securing mineral supply is framed in technological terms and technological innovation is seen as key to doing so. Driven by increasing concerns over securing supply of raw materials and growing awareness of the need to manage all finite resources in a prudent and responsible manner, policy makers and regulators are beginning to appreciate the importance of safeguarding access to mineral resources. Countries that view minerals as a security issue typically focus on the identification and stockpiling of critical minerals. By designating minerals as critical for national security and development, policies are designed to control mineral flow and secure supply of critical minerals. State resources are used to gain access or acquire these critical minerals.
- The US, China and Japan explicitly protect and further national interests with a strategic objective in mind.

Policy measures

This study identifies a number of policy measures that are particularly relevant in securing the supply of minerals. These policies can be used at a national and an international level. These policy measures include:

- *Securing mineral supply at the national level*. Direct state involvement is used by a number of countries (amongst others the US, China, and Japan) to strengthen governmental grip on the supply of minerals.
- *Increasing domestic capacity*, particularly mapping, extracting and refining minerals is an important aspect of securing mineral supply at the national level, especially for resource rich countries.
- *Securing mineral supply at the international level*. Several countries actively pursue policies at the international level to improve access mineral supplies.

They do so through establishing strategic partnerships with important producer countries. Further, several countries aim to create open markets and a level international playing field through international rules, regulations and regulatory institutions.

Impact of scarcity

- The impact of scarcity can be expected to increasingly affect the entire value chain. Minerals might be mined in countries where it is not economical to do so, simply to guarantee a minimal degree of self-sufficiency.
- Large companies backed by their states of origin are likely to compete intensely to gain concessions for foreign direct investment in the mining sector of resource rich countries; even if these investments are risky, not particularly profitable, or take place in countries with authoritarian regimes and a poor track record on protecting human rights and environmental standards.
- Instead of being available to competitive bidding on global markets with equal access, scarce minerals might be increasingly traded through long-term supply contracts arranged between major corporations with heavy government involvement. Such deals might include preferential terms for political allies or include political concessions, promises of development or military aid or technology transfers.
- Supplies might be even entirely denied to countries that are regarded as adversaries. In resource poor countries, consumption of certain minerals might be temporarily rationed or otherwise restricted. Governments in these countries might seek to focus R&D on substituting elements that are mainly mined by hostile or unstable political regimes. Similarly they might seek to create or expand strategic reserves of certain elements as buffer against supply disruptions.

Europe

From a European point of view, increasing mineral scarcity is particularly worrisome, because only very few metallic mineral deposits worth exploiting are found on the continent.

- For a large number of metallic minerals, Europe is overwhelmingly dependent on foreign supplies to satisfy it's industries demand, including many doping agents that are vital to products and production processes in the continents extensive high-tech sector.

- China dominates world production of many strategic minerals; for many of these minerals China has proposed new, or reduced existing export quotas. Such policies are detrimental to European interests because they increase global mineral scarcity and weaken the position of European industry vis-à-vis their competition.

Europe's policy response to this emerging challenge has been rather slow and hesitant. A hard and united European position on these issues should be actively promoted in multilateral fora like the WTO, World Bank, or the G-20.

Simultaneously, Europeans should demand that allies in the G-8, NATO, World Economic Forum, OECD and similar institutions join the EU in actively protecting and promoting the free market principle in mineral markets.
How successful Europe and the rest of the world is going to be in coping with the challenge of mineral scarcity will depend mainly on four key factors:

1. The development of energy scarcity, as energy is required key to mineral mining.
2. The success in substituting scarce elements, particularly in key high and emergent technologies.
3. The extent to which mineral consumption per capita can be reduced in affluent societies, and scarce mineral resources will be re-used and recycled globally.
4. The balance between increasing geological and geographical distance, and R&D in mining technology.

1 Introduction

Minerals, like fossil fuels or water, are among the principal natural resources that provide the material foundation of our economies. Minerals are the natural product of geological processes and occur as solid matter with highly ordered atomic structures in the crust of the planet. Each of the over 4000 known different types of minerals has its own characteristic chemical composition and specific physical properties. (For definitions of terminology used, see Annex C and D).

Only a fraction of the known minerals exists in greater quantities. Some of these are mined, refined and processed. This includes breaking them up into their elemental components, which are recombined into different types of materials. These materials are then used to manufacture a wide array of products that form the backbone of our modern economies, from LCD displays to fighter jets and mobile phones to skyscrapers.

Without minerals, industrial society and modern technology would be inconceivable. If fossil fuels are the proverbial lifeblood of the global economy, then minerals are certainly its bone marrow. How pervasive minerals are in the economy and how dependent advanced societies are on them, may be illustrated using the example of this report: In its printed form, nickel, chromium and molybdenum were needed to create the machines capable of turning wood into pulp.

Then, gallium, selenium, nickel, aluminium, silicon and copper were required to build the laser printer that applied the inks to the pages as well as the computer that connected to it. Zinc, manganese and iron were needed to build the components of the heavy transport trucks that delivered the paper, printer, and computer to their respective parties. All these elements have to be first extracted from minerals, which in turn need to be mined form the earth's crust.

Minerals have been mined and processed for thousands of years. However, the relatively small quantities that pre-industrial societies have mined, pale against the amounts of minerals that are needed to satisfy modern industrial societies' need for minerals. To satisfy the appetite for minerals of a rapidly industrialising world, growing economies and a growing world population, ever greater quantities of minerals are extracted. The question that arises is if we might not at some point in the future simply run out of minerals. And if we run out, when will that be? And what will the consequences be?

These questions stand at the heart of the debate on mineral scarcity, which, like the debate on scarcity of fossil fuels or fresh water, has enjoyed considerable conjuncture in recent years. Policymakers and the public are confronted with warnings about the potential negative effects of mineral scarcity. A number of experts predict that, fuelled by the growth of large emerging economies and China in particular, the global demand for minerals will keep increasing steeply and suppliers will have great difficulty to keep pace, as they have to turn to ever more distant and lower quality deposits. Therefore, so the argument goes, the world will experience a series of price hikes and supply disruptions, which will have a debilitating impact on the global economy and may result in conflicts between countries that control the access to valuable mineral resources and those who don't. The fact that a number of major countries have policies which seek to secure their own supplies and to maximize the benefits from mineral deposits on their territory, has further added to the credibility of such scenarios.[1]

This report analyses the security implications of mineral scarcity. It examines how real the threat of mineral scarcity is and how it will impact on national security in the coming years. It also examines how policy approaches in ten different producer and consumer countries, as well as international organizations, have been developed to deal with potential mineral scarcity.

1 The United States, Japan and China are examples of countries that employ such types of policies. For the U.S., see United States Congress (1980), National Materials and Minerals Policy, Research and Development Act; for Japan, see Japanese Ministry of Economy, Trade and Industry (2008), Guidelines for Securing Natural Resources; for China, see Chinese State Council (2003), China's Policy on Mineral Resources.

2.1 Research strategy

In order to answer the above questions, HCSS collected and analysed empiricaldata on scarce minerals. The data collected included:

- the physical and geological properties of selected minerals;
- current and likely future technological applications;
- prices;
- geographical distribution patterns of mining and reserves;
- national and transnational policies on production, use, and trade.

In order to collect these data, HCSS selected fifteen individual elements. Two groups of elements, rare earths elements and platinum group metals, were also added to the sample (see figure 1). Focusing on a smaller set of elements – rather than a larger set of minerals that contain these elements in various combinations and concentrations – simplified the analysis, as most price or production data on minerals are quoted per ton of elemental content. In all, HCSS collected data concerning 40 of the 94 naturally occurring elements.

The sample was selected according to three criteria: First, the importance of these elements for the industrial sector, with special emphasis on high-tech industries. Second, the sample included elements for which few substitutes are known, as society is particularly vulnerable to shortages in these minerals. Third, the sample included elements which are crucial to emerging technologies, with particular emphasis on alternative energy and other 'green technologies'. The sample of fifteen elements and two element groups can be divided into three categories: mass consumables, doping agents, and precious metals (see Figure 1).

Mass consumables refer to elements which are used in large quantities throughout the global economy in manufacturing products or materials. The most well-known is copper, whose resistance to corrosion allows for various bulk applications, ranging from e.g. inductors, to pipes for drinking water to rust resistant roofing. Mass consumables are sometimes used in very small quantities in final products. Due to their high electro-conductivity, they are used in miniscule quantities in semiconductors and integrated circuits.[2]

2 Pratt, A. (2004), Overview of the Use of Copper Interconnects in the Semiconductor Industry., Advanced Energy Inc. Occasional Paper. http://www.advanced-energy.com/upload/File/White_Papers/SL-ELECTROPLATING-270-01.pdf

MASS CONSUMABLES	DOPING AGENTS	PRECIOUS METALS
COPPER	**GALLIUM**	**PLATINUM GROUP:**
MANGANESE	**LITHIUM**	Platinum
NICKEL	**MOLYBDENUM**	Palladium
TIN	**NIOBIUM**	Rhodium
ZINC	**HAFNIUM**	Ruthenium
	TANTALUM	Osmium
	TUNGSTEN	Iridium
	ZIRCONIUM	
	RARE EARTH ELEMENTS:	
	Cerium	
	Dysprosium	
	Erbium	
	Europium	
	Gadolinium	
	Holmium	
	Lanthanum	
	Lutetium	
	Neodymium	
	Praseodymium	
	Promethium	
	Samarium	
	Scandium	
	Terbium	
	Thulium	
	Ytterbium	
	Yttrium	

Figure 1. ELEMENTS SELECTED IN THE HCSS DATABASE

Doping agents (or *dopants*) are generally produced in much smaller quantities. They are used as additives in composites or alloys, where they convey new and unique properties to the compound material. For example, 0.04% of Lithium is required to produce Brahnmetal, a lead-copper alloy used for the production of antifriction beams for railways and heavy duty bearings.

The term doping agent technically applies only to elements that are used in very small quantities to alter optical or electrical properties within the semiconductor industry. In the context of this report, we use the term more broadly to refer to any element that is used in very small quantities to confer significant properties onto compound materials. Often doping agents also have their 'own' applications where they are used in greater quantities, such as lithium in batteries, hafnium in control rods of nuclear reactors or tantalum in warhead liners.

A subset of doping agents are the so-called *rare earth elements.* Rare earth elements refer to the lanthanide series (57-71) on the periodic table, plus the two elements immediately above this row, yttrium and scandium. Generally, elements higher up in the periodic table get larger in size, or atomic radius, as they have more protons and neutrons. However, rare earth elements share a unique property called 'lanthanide contraction', which makes them shrink in size as they gain protons. This phenomenon has crucial implications for their commercial application, as lanthanide contraction allows rare earths to be combined to an exceptional degree with other elements in compounds or alloys. This creates materials with unique properties that provide the basis for a wide range of high-tech applications. Lanthanide contraction makes rare earth elements difficult to separate from one another. Prior to the 1930s, no commercial processes for isolating rare earth elements existed. The minerals that contained them were used in their undivided form, e.g. to create so called *Mischmetal*. This explains why they are often grouped together in a single category, despite great diversity in application and abundance.

Rare earth elements, other than their name suggests, are not particularly rare. A number of rare earth elements exist within the earth's crust at greater abundance than other more widely utilized elements such as lead, tin or gold. However, they are far more scattered throughout the environment than some other elements that are in lower abundance, making them particularly challenging to mine. *Precious metals* are mined in even smaller quantities than doping agents. Known for their special resistance to heat and corrosion as well as high electro-conductivity, precious metals are employed in both industrial processes and commercial end-products. Precious metals are used as catalysts for petroleum refinement, or in very small quantities as addition to titanium in electronics. Yet, the most unique aspect of the precious metals is the fact that they are used as reliable investment assets in global financial markets. This has significant ramifications for their price and availability, particularly during periods of economic instability.

A subset of precious metals is the *platinum group metals*. These were known as by-products of gold, nickel or silver production until the beginning of the 20th century. As the elements lacked commercial applications and had similar properties, they were grouped together and treated as waste products. Since the 1920s, the platinum group metals have become increasingly important, especially for the energy industry where several of the elements are used as catalysts in chemical reactions. Additionally, platinum fuel cells as well palladium, which is able to absorb more than 900 times its weight in hydrogen, are increasingly being viewed as a critical resources for any future 'hydrogen economy'.[3]

Following the collection of data on these elements, HCSS constructed a database. The database contains for each element and the two element groups time-series on global output, world market prices, and the quantity and geographic distribution of global reserves. These data were collected from the US Geological Survey (USGS), other national surveys and a variety of additional sources. The data covers the period between 1900 and 2008. While not all data are available for each year and element, many series cover the entire period and the database as a whole gives a good indication of general trends in the data. Consumption estimates and data on recycling output are unfortunately not available on the global level. Where appropriate, data on US consumption and recycling were used as rough indications instead.

Finally, HCSS analysed national mineral policies in ten advanced economies and emerging markets, as well as for eight international organizations. These data were assembled in a database which provides the empirical foundation for this report.

Chapter 2 describes the conceptual framework for mineral scarcity. Chapter 3 presents the findings of our data research on mineral scarcity. Chapter 4 analyses national policies to address mineral scarcity. Chapter 5 assesses the security and geopolitical impact of mineral scarcity. The last chapter contains conclusions and recommendations.

3 Wicks, G. (2009), Materials Innovations in an Emerging Hydrogen Economy. Hoboken: John Wiley and Sons.

2 Understanding scarcity: a conceptual framework

The public debate on rare minerals, like similar debates on fossil fuels, is dominated by an often implicit, intuitive conception of scarcity, which may be referred to as the *static scarcity paradigm*.[4] The key assumptions of this paradigm are straightforward: There is a fixed, even if not necessarily exactly known amount of rare minerals on the planet. Ongoing mining and consumption of these minerals diminish these finite reserves, with the speed of extraction and consumption determining the rate of depletion. In the static paradigm, scarcity sets in when cumulative human consumption has depleted reserves to the degree that production struggles to meet demand. Existing deposits have been exhausted and new ones are ever smaller and more difficult to find. A Malthusian endgame-scenario is the consequence, as consumers scramble to secure the little that is left, prices skyrocket, supply shortages occur, and fierce conflicts ensue over the control of residual reserves.

The key metric in this static conception of mineral scarcity is the so-called *static range*, which is the estimate of time left until depletion of a given mineral. Uncertainty in determining the static range of a given mineral stems from two sources: uncertainty about the precise path of future consumption, and uncertainty about how much exactly is left in the ground. However, taking these uncertainties into account, estimates of static ranges are in principle calculable, even if margins of error remain. Figure 2 shows a number of estimates for static ranges of several different elements.[5]

In this static scarcity paradigm, there are only two ways to escape the scourge of scarcity. First, time may be bought by stretching static ranges through less

4 See for example Tilton, J.E. (2003), 'Assessing the Threat of Mineral Depletion in Minerals and Energy.' Raw Materials Report, Vol. 18, No. 1.

5 The Hague Centre for Strategic Studies (2008), 'Future Issue: Scarcity.' The Hague Centre for Strategic Studies Future Issues, No. 1.

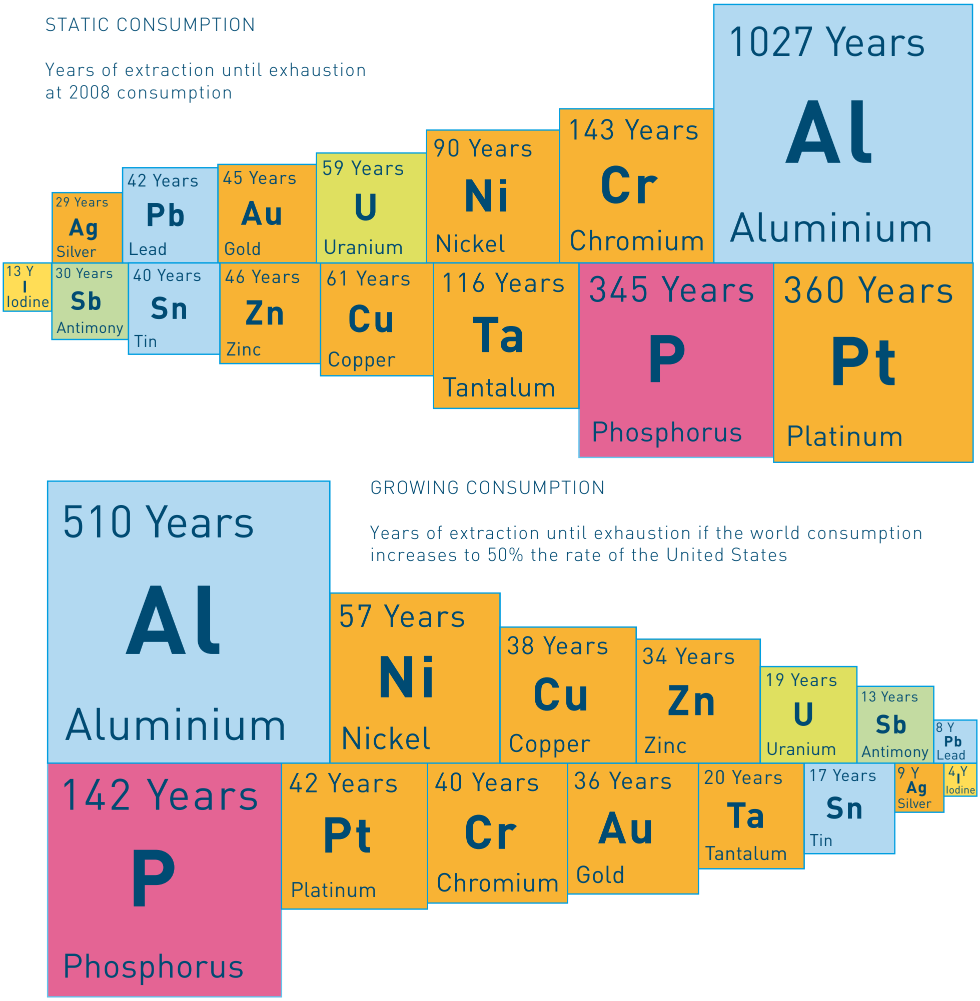


Figure 2. ESTIMATES OF STATIC RANGES (YEARS OF EXTRACTION) BY STATIC OR GROWING CONSUMPTION

and more efficient consumption (e.g. by reducing, re-using and recycling). Second, technological progress may allow substituting minerals that are close to depletion with others that are more abundant, and thereby help to escape the scarcity trap.

2.1 The dynamic-adaptive scarcity paradigm

The static scarcity paradigm has dominated the attention of the public and policymakers because it is intuitive, logically coherent, and allows for clear-cut conclusions and policy-recommendations. However, it is imperative to understand that the static scarcity paradigm suffers from a number of fundamental conceptual flaws that do not allow it to adequately capture the much more complex realities of mineral scarcity. The most powerful indication that the static scarcity paradigm is flawed comes from the reserve data for different elements, which provide the basis for estimates of static ranges. Figure 3 shows that reserve figures have been stable or even increasing at times, despite ongoing and constantly expanding production. This fact cannot be explained in the static scarcity paradigm. At most, it might allow for occasional upward corrections

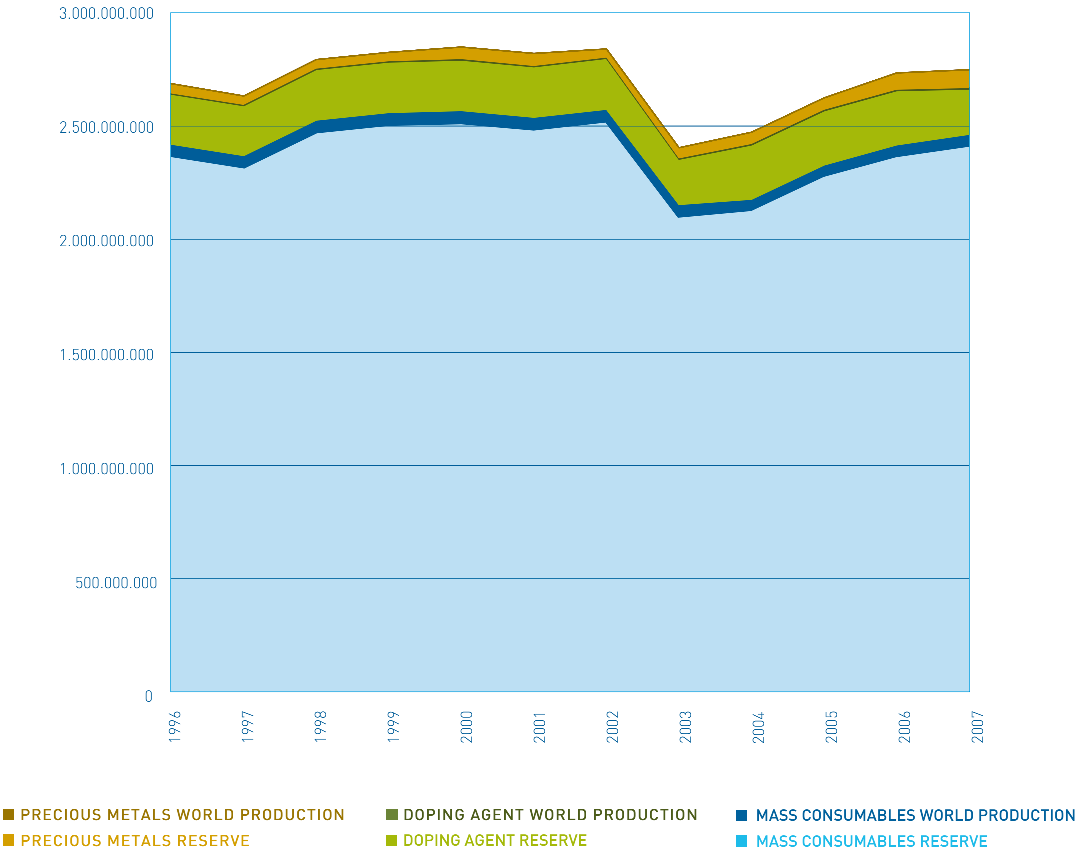


Figure 3. RESERVES AND PRODUCTION OF SCARCE MINERALS OVER TIME IN TONNES. SOURCE: HCSS DATABASE

of reserve data in case of new unexpected discoveries, but in between such spikes, the long-term trends in reserve figures should be negative, as production exhausts an ultimately finite amount of reserves.

The explanation for this apparent contradiction is the fact that reserve data by national geological surveys do not indicate the absolute quantity of an element that is available for extraction, as the static paradigm would suggest. Instead, reserve data provide an estimate of the small fraction of the very large amount of minerals that exist on the planet, which is *profitable for extraction now or in the near future with existing technology and under current market conditions*. In other words, reserve data capture a dynamic equilibrium that continuously adapts to the complex interplay of our evolving knowledge of the geological environment, changing market forces, and progressing extraction technologies. Even while the cumulative amount of minerals extracted from the planet keeps ever increasing, reserves may remain stable or even grow where technological innovation takes place or market conditions change. Similarly they may decline, e.g. where spikes in energy prices make extraction at high energy intensities less profitable.
This conceptual understanding is important to the scarcity debate. It does not imply that scarcity of minerals is not an issue. However, it shows that scarcity is a more complex phenomenon than the deceptively straightforward idea that is implicit in calculations of static ranges. From the dynamic adaptive viewpoint, scarcity is a permanent feature of human existence: minerals are scarce as long as they are valued in society and cost time and effort to extract from the environment. The crucial questions are *how much* they are valued and how much time and effort it takes to extract them. Where the static paradigm tries to determine if minerals are 'scarce or not scarce', the dynamic adaptive paradigm revolves around the more realistic question of how scarce minerals are, relative to all other goods and services in society.

2.2 How scarce are minerals on the planet?

Reserve data for a given element do not represent the total quantity of that element present on the planet. However, even if one understands that reserve figures present a relative economic variable and not an absolute physical constant, the question of how much of a given element is physically present in the system is relevant. The short answer is invariably 'a lot', even for the rarest elements that are mined by humans. A brief examination of the physical state in which these elements are found on the planet demonstrates the irrelevance of such numbers for the scarcity debate. For any element, most of what is found of it on the planet is finely dispersed throughout the environment, dissolved in the ocean, the air or in the cells of plants and animals. At present there are no technologies available to extract elements found in these dispersed states on an industrial scale. The only physical state in which elements are presently extractable is where they occur as minerals, i.e. highly concentrated clusters of multiple elements that have formed through natural geological processes in the topmost layer of the planet, the earth's *crust*. Minerals in the crust can be located and mined mechanically by humans.

2.3 How scarce are minerals in the earth's crust?

If the total amount of an element that is present on the planet is irrelevant to its scarcity, one might rather ask how much of it can be found in mineral form in the earth's crust and therefore could, at least theoretically, be mined. The majority of the 4000 known minerals are too scattered to be extracted. The threshold that separates elements in their mineral form from their dispersed states, in which they can no longer be separated mechanically, is called the *mineralogical barrier*, which is presented in figure 4.

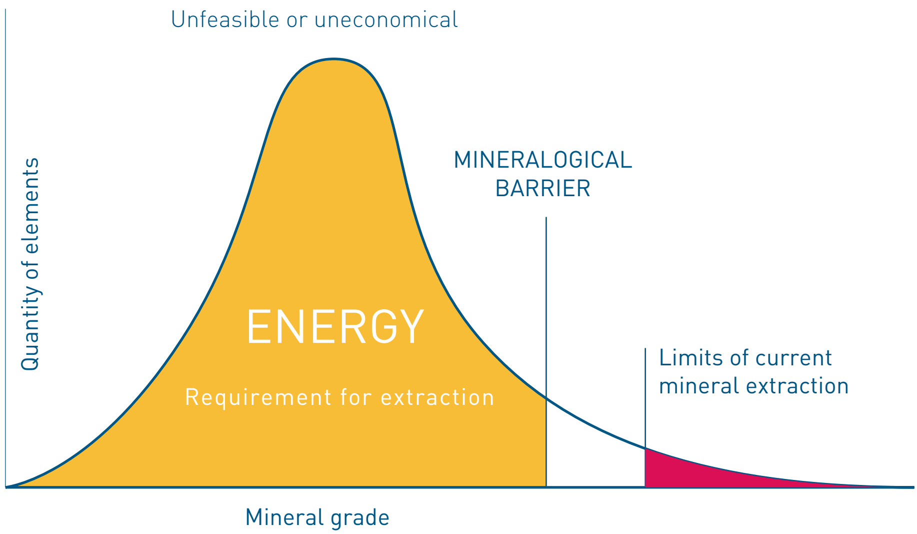


Figure 4. DISTRIBUTION OF ELEMENTS ON THE PLANET[6]

6 Based on Skinner, B.J. (1976),'A Second Iron Age Ahead?' American Scientist, Vol. 64, pp. 258-269.

Estimates of how big a fraction of a given element exists in the form of theoretically mineable minerals are highly speculative and vary from source to source. It has been estimated that, depending on the element, between 0.01% and 0.001% of the total amount found in the earth's crust occurs in mineral form. This is a very small part of the earth's volume, but these are enormous numbers compared to the quantities of elements that have been extracted so far. Even if annual production skyrocketed to the total sum of production in the 20th century, the earth's crust e.g. would contain enough minerals to continue the production of aluminium for 57 billion years and that of gold for 5 million years. Based on the amount of minerals contained in the earth's crust, scarcity would thus be a non-issue.

2.4 How scarce are minerals that can be mined profitably?

Again, however, these benign numbers are irrelevant to the scarcity debate. The ability to access and collect the elements is of far greater relevance to future scarcity than absolute abundance. While minerals are highly concentrated natural states of elements, mining operations are technically and economically feasible only at sites where minerals are densely clustered in geological formations. In other words, such *ore deposits* must have a sufficiently high *ore concentration* (i.e. mineral content), to make mining practically and economically viable.

Furthermore, deposits must also be large enough to justify the enormous overhead costs necessary to set up a new mining operation: small deposits, even if they have high ore grades might not generate enough output over their life time to justify extraction. Ore deposits with sufficient concentrations of minerals must also be accessible enough to allow for extraction. The earth's rust is between 10 and 50 km deep, and the world's deepest mine, located in Johannesburg, South Africa, is 'only' 3.7 km deep. Also, much of the earth's surface is covered with oceans which are difficult to access for mining operations.

Only a tiny fraction of all minerals contained in the earth's crust are found in such highly concentrated and accessible deposits. Only a tiny fraction of all minerals contained in the earth's crust are found in such large high-grade, easily accessible deposits that profitable mining becomes possible. The reserve data available from national surveys are rough estimates of the aggregate elemental content of all the deposits that are in principle accessible with current mining technology *and* have the necessary size and ore concentration to make extraction profitable at current market prices (see figure 5).

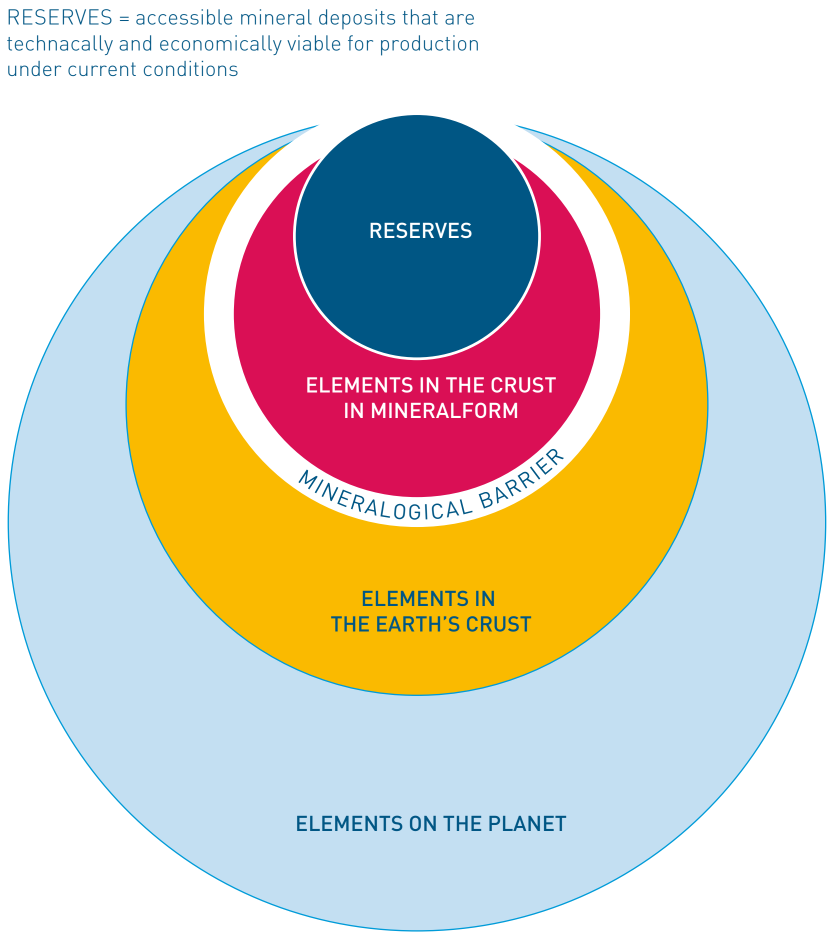


Figure 5. ELEMENTS ON THE PLANET

The bottom line is that when examining scarcity of individual elements that are crucial to the functioning of our economies and advanced technologies, estimates of absolute amounts, either in terms of quantity of the element that exists on our planet or even in terms the fraction of this quantity that is found in mineral form in its crust, are irrelevant. What matters instead are *reserves* –

i.e. the elemental content of the small fraction of relatively large deposits that are known to have relatively high ore grades and lie in relatively accessible parts of the earth's crust. Reserve data adjust dynamically because what is large, accessible, and concentrated enough to merit extraction changes continuously as demand, technology, and our knowledge of physical deposits evolve. Figure 5 schematically illustrates this relationship between reserves and different forms in which elements are found in the environment. Elements in the kernel of the earth are seen as not extractable.

2.5 Mineral scarcity and adaptive response

Scarcity in the adaptive dynamic paradigm is thus above all a question of scarcity in the global market place. A state where a mineral just disappears from the planet like a species that is hunted to extinction will not occur. However, continuing large-scale extraction may well lead to situations where, relative to available technology, easily accessible, high-grade deposits have been depleted. Continued burgeoning demand may then lead to steep price increases, as producers struggle to expand output based on less accessible deposits with lower ore grades and much higher production costs.

It is part of the adaptive nature of the market system that producers and consumers as well as national governments seek to adapt to scarcity. As prices of products based on particularly scarce elements rise rapidly, consumers seek to reduce their consumption of these goods. Companies that manufacture these products substitute these elements with more abundant ones as far as possible and direct their R&D departments to develop alternative products or inputs that rely on cheaper minerals. Recycling will become more profitable and will increase in volume. All these efforts could reduce demand for particularly scarce minerals over time.

Simultaneously, mining companies begin to mine deposits that were previously considered uneconomical because of their size, ore grade or inaccessibility. They also invest heavily in exploration to find previously undiscovered deposits of particularly scarce and therefore valuable minerals. This will increase output over time. Taken together, falling demand and increasing production in response to high prices will mitigate scarcity to some degree. The system adapts and scarcity in the market place decreases. This could suggest that scarcity is not a problem as market participants autonomously adapt and mitigate scarcity. However, such adaptation processes can take many years if not decades. Mineral exploration and the setting up of new large-scale mining operations have lead times in the order of five to seven years, excluding exploration. Demand is similarly inelastic, as substitutes are often not readily available and due to the long time it may take to develop alternative products or production processes that rely on more abundant minerals.

In the meantime, this may lead to volatile, tight markets that are increasingly vulnerable to disruptions: Already small reductions in output quantities or increases in demand can lead to fierce price hikes and shortages, where particularly scarce minerals are temporarily no longer obtainable in global markets in the quantities that consumers are willing to buy. Export restrictions or strategic stockpiles instituted by states that seek to secure supplies and protect national industries can further exacerbate the situation. The classical example of how serious the effects of such 'short-term' scarcity hikes in key commodities can be on society, are the Oil Shocks that lead global disturbances in the 1970s and early 1980s.

Furthermore, where production costs keep increasing and demand rapidly expanding, long-term prices may also increase permanently. The consequence of such structural increases in real prices is that societies that are unable to reduce their reliance on scarce resources will experience lower material welfare and economic growth: collectively more resources and efforts must be invested to obtain the same amount of indispensable minerals, leaving less available to seek other goods and services that are valued in society. Conceptualized in dynamic terms, scarcity is a much more transient and complex phenomenon than what is suggested in the static paradigm, but this does not mean that it cannot cause very serious problems with grave consequences for society.

2.6 Dynamic ranges?

In the static paradigm, static ranges indicate the point where reserves are depleted and the point in time where scarcity will become debilitating. In the dynamic perspective, predicting the point where scarcity becomes a real problem is much more complex. Recognizing scarcity as adaptive-dynamic phenomenon means that it can increase and decrease over time. Understanding the fact that mining companies, governments, producers, and consumers autonomously adapt to (perceived) scarcity implies feedback effects that mitigate or sometimes exacerbate scarcity. Instead of only consumption and static reserves, scarcity in the dynamic paradigm depends on market prices, evolving mining and refining technology, previously made investments into exploration and development of new mines, the elasticity of demand and supply, and government policies. The large number of factors that will determine scarcity in the dynamic paradigm and the multiple feedback loops add considerable levels of uncertainty that make it impossible to precisely predict when supply shortages will occur and at what point heightened scarcity will become a problem.

Instead of making unrealistic predictions about an uncertain future, the dynamic adaptive framework for analysing scarcity calls for identifying broad general trends in demand, production, reserves, technologies, and policies, in order to make interferences about the possible future development of mineral markets and their vulnerability to disruptions and shortages that might have serious consequences on the broader society.

Findings

This chapter discusses the findings from our data gathering on minerals. The data covers price developments, geographic distribution, production, recycling and reserve data on 15 individual elements and two element groups, the platinum group and rare earth elements, from 1900 until today. Most of the data stretch back to the beginning of the 20th century. What emerges from this data is that global output has expanded exponentially and probably faster than growth in global demand. There is a downward trend in prices over the same period of time. Overall, the results show that scarcity has slightly decreased over the 20th century.

3.1 Price developments

There is a relatively stable trend of mineral prices over the course of the twentieth century. However, relatively long periods of stable or decreasing prices are interrupted by shorter periods of increased volatility and violent price spikes.

Interestingly, over the past decade, real prices have increased steeply. It is difficult to judge at this point, whether this indicates a shift towards an environment of increased scarcity, or if this development is consistent with the pattern of steep but ultimately temporary price hikes that were observed several times over the course of the 20th century.

A crucial element in gauging the scarcity of minerals is world market prices. They reflect the equilibrium of global demand and supply in markets and are an indication of how minerals are valued relative to other goods and services. Prices may be 'distorted' at times (e.g. due to anti-competitive practices or price controls) or reflect unrealistic expectations about future output or consumption. However, even where this is the case, they provide a pivotal indicator of scarcity in the global mineral market. This is because actors in mineral markets orient their consumption and production decisions at price incentives, even where they might not accurately reflect underlying realities. In other words, in the absence of rationing, the price *determines* the scarcity consumers and producers encounter in their own economy, even where prices are out of sync either with world market developments or based on unrealistic assumptions about future demand and supply.

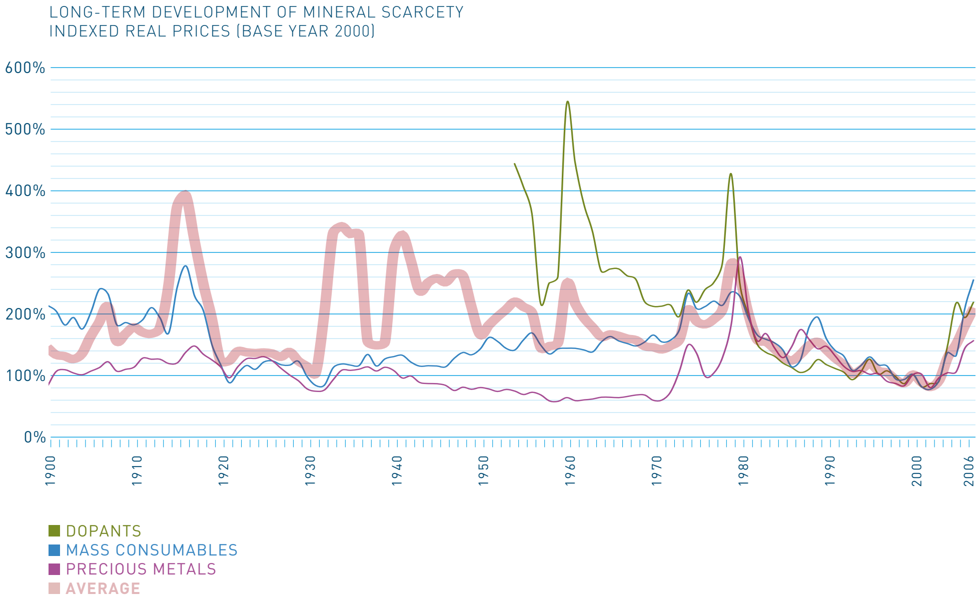
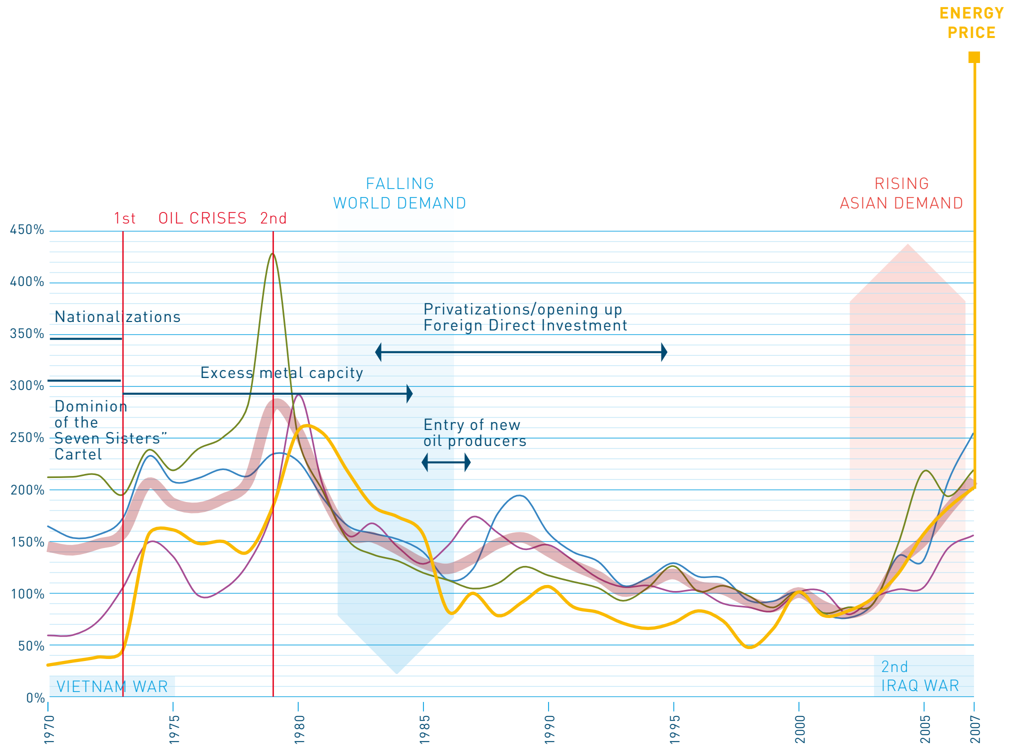


Figure 6. REAL PRICES OF MINERALS 1900-2007

In figure 6 we have depicted aggregate price data over time for precious metals, mass consumables and doping agents. Compiling long time-series on market prices for specific elements is a more difficult undertaking, because records of nominal prices are patchy and show data for units of bulk commodities traded in a specific market place, rather than average prices for elemental content across markets. For the above graph, we use per-ton of elemental content estimates from the US geological survey. These are compiled based on average year-end prices on US markets, resulting in price series ranging from the early 19-hundreds to the present day. In order to make prices comparable over time, the data shown in figure 6 are adjusted for inflation. To make price developments comparable across the different elements with different per-ton prices, the real prices have been indexed, with the year 2000 chosen as base year (100%). This methodology allowed us to analyse long-term trends in scarce minerals and to compare current price levels to historical data.

Several inferences can be made from the price data as depicted in figure 6. First, real mineral prices have been fluctuating quite strongly over the course of the twentieth century. In several instances, average prices across all minerals in our sample came close to doubling over the course of a couple of years (e.g. during World War I or the Oil Shocks of the 1970s), but then quite quickly retreated again approximately to their levels of departure. Between such spikes, there are also longer periods of relative stability which are generally associated with weak downward trending of aggregate prices. Over the entire sample period, the price of scarce minerals relative to other goods and services has remained roughly stable.

It is interesting to have a closer look at the last three decades of price developments. While prices have fallen for over two decades after spiking sharply in the 1980's, this trend has reversed over the past couple of years. Real prices have more than doubled since 2002 and have reached a level they haven't seen since the second oil shock nearly three decades ago. At this point it is premature to say if this indicates a permanent change in the trend of mineral prices towards scarcity or a temporary spike as global mineral markets experienced several times in the 20th century.



ENERGY-MINERAL RELATIONSHIP
INDEXED PRICES (BASE YEAR 2000)

1 YEAR LAGGED CORRELATION MINERAL AND ENERGY PRICES

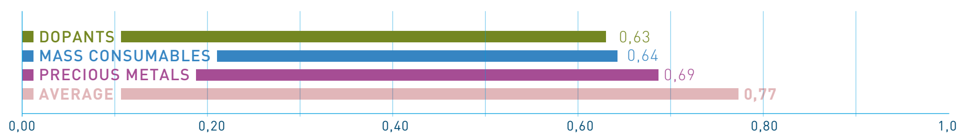


Figure 7. COMPARISON OF CRUDE OIL PRICE AND MINERAL PRICES

In figure 7, we have compared the development of crude oil prices and mineral price data over a thirty-year period from 1970, to see whether there is a connection. Crude oil prices are a relatively suitable approximation of the development of the price of global energy prices and they matter to mineral prices as energy is a key input in mineral production because mining, refining, and transportation of minerals is are extremely energy intensive processes. Figure 7 indicates that the development of mineral prices is remarkably in sync with the evolution of the crude oil price series. In statistical terms, the raw correlation between crude oil prices and average mineral prices of the following year is an astonishingly strong 0.77; and still above 0.6 for each of the subcomponents. It is interesting to note that the recent upward trend in mineral prices corresponds closely to the simultaneous rise in real oil prices.

It is premature to draw too strong conclusions about the interlinkage between mineral and energy scarcity which the data appear to suggest. However, the relationship between energy and mineral prices is an issue with potentially important ramifications for the scarcity debate. This issue requires further inquiry. The price data present above raise the question why minerals have become cheaper in real terms over the last century, i.e. less scarce relative to other goods and services. In the same vein, does the price increases witnessed since 2000 reflect a changing trend towards increasing mineral scarcity in the 21st century?

A simple explanation for the downward trend in mineral scarcity witnessed over the past century would be falling demand. However, one can safely exclude this explanation, even if aggregate consumption data for scarce minerals on the global level are not available. As the world population increased manifold in size and simultaneously industrialised rapidly, global mineral demand has increased steeply over the past century. Where available, consumption data on the national level confirm this pattern. But if demand has been increasing what explains that prices have remained stable or have been falling? The answer is to be found on the supply side.

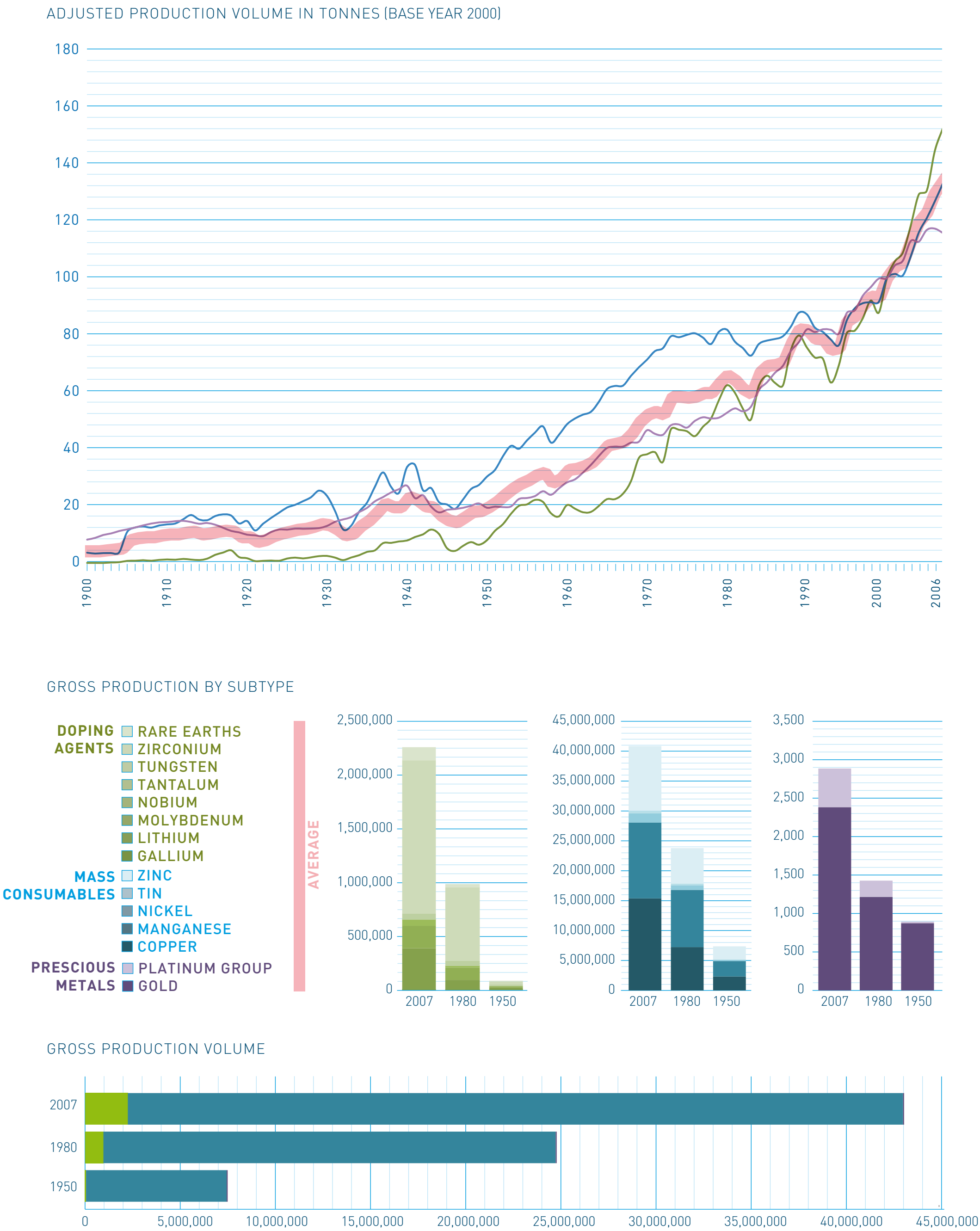


Figure 8. HISTORICAL DISTRIBUTION OF PRODUCTION.Source: HCSS database.

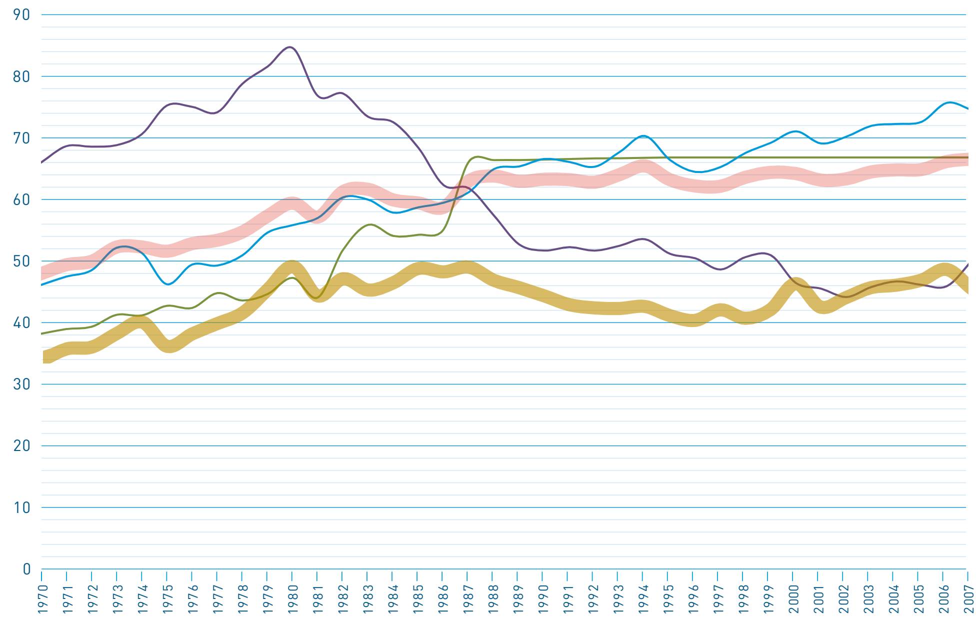
3.2 Production

The production of scarce minerals has expanded rapidly over the course of the last century. Figure 8 depicts the growth in production of mass consumables, doping agents and precious metals over the course of the 20th century. This graph shows that until 2000, global output on average had increased fivefold since 1950.

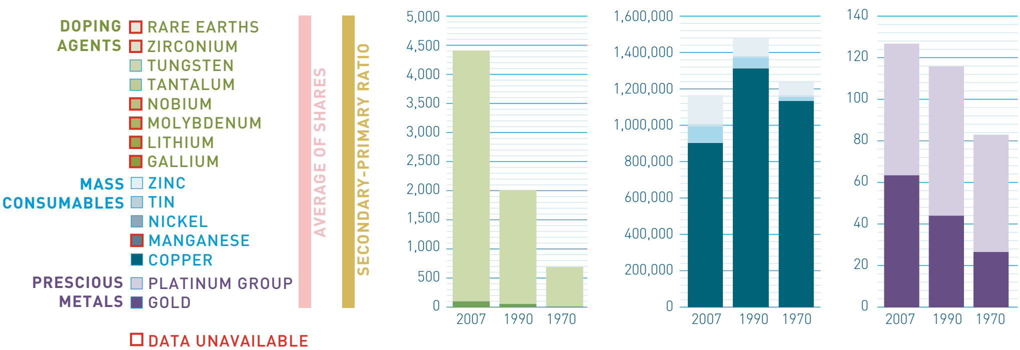
Until 2007, production again grew by 17% in the case of precious metals, by 33% percent in the case of mass consumables, and by 46% percent in the case of doping agents.

The lower part of figure 8 shows that the growth patterns and the volume for the different groups of minerals vary. While mass consumables are mined in volumes of tens of millions of tons per year, only a few million tons of doping agents and a just few thousand tons of precious metals are supplied to global mineral markets annually. Figure 8 also shows that the growth of production of minerals has been uneven. For example, the growth of platinum group metals has e.g. significantly outpaced the expansion of gold production within the precious metals category.

US SECONDARY PRODUCTION VOLUME IN TONNES SHARE BY SUBTYPE INDEX (BASE YEAR 2000)



US GROSS SECONDARY PRODUCTION BY SUBTYPE



US GROSS SECONDARY PRODUCTION VOLUME

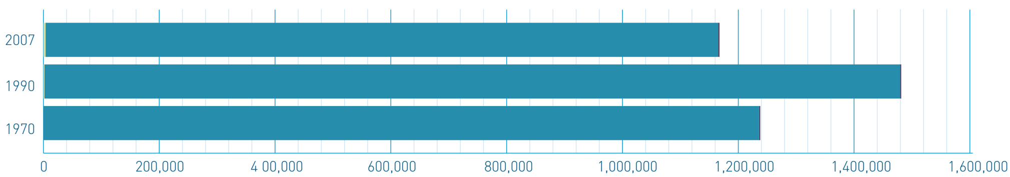


Figure 9. SECONDARY PRODUCTION PROPORTIONATE TO PRIMARY PRODUCTION OVER TIME. Source: HCSS database.

3.4 Secondary production

The aggregate production figures presented above mask the fact that by no means all supply to global mineral markets is the product of extracting resources from the natural environment through mining, so-called 'primary' production. Instead, a sizeable fraction of global production comes from 'secondary production' or recycling.

Aggregate data on the share of secondary production in global output is not available. In order to get some indication of secondary output, we have looked at US secondary production data for a substantial amount of elements over several decades. Figure 9 shows historical time series of the share of aggregate secondary production in total US output for the elements in the HCSS database, for the period from 1970 to 2007.

For those of the 15 elements and two element groups for which data is available, the average share of total secondary production in the US amounts, depending on the aggregation method,[7] to approximately 40 to 60 percent of primary production in 2007. The picture for secondary production of individual elements is less stable. This is because recycling of individual metals fluctuate with market price developments, environmental regulations, technological limitations, advancements and costs, the amount of energy required for recycling, re-distribution between producing countries and subsequent changes in availability and the amount of recyclable materials and products within which the metal is used in primary production.

7 Averages of secondary production shares can either be calculated by averaging percentage shares across each element, or by looking at the share of the volume of secondary production in total output. The former biases the average towards elements that are produced in smaller quantities, while the latter emphasises those elements that are produced in large quantities.

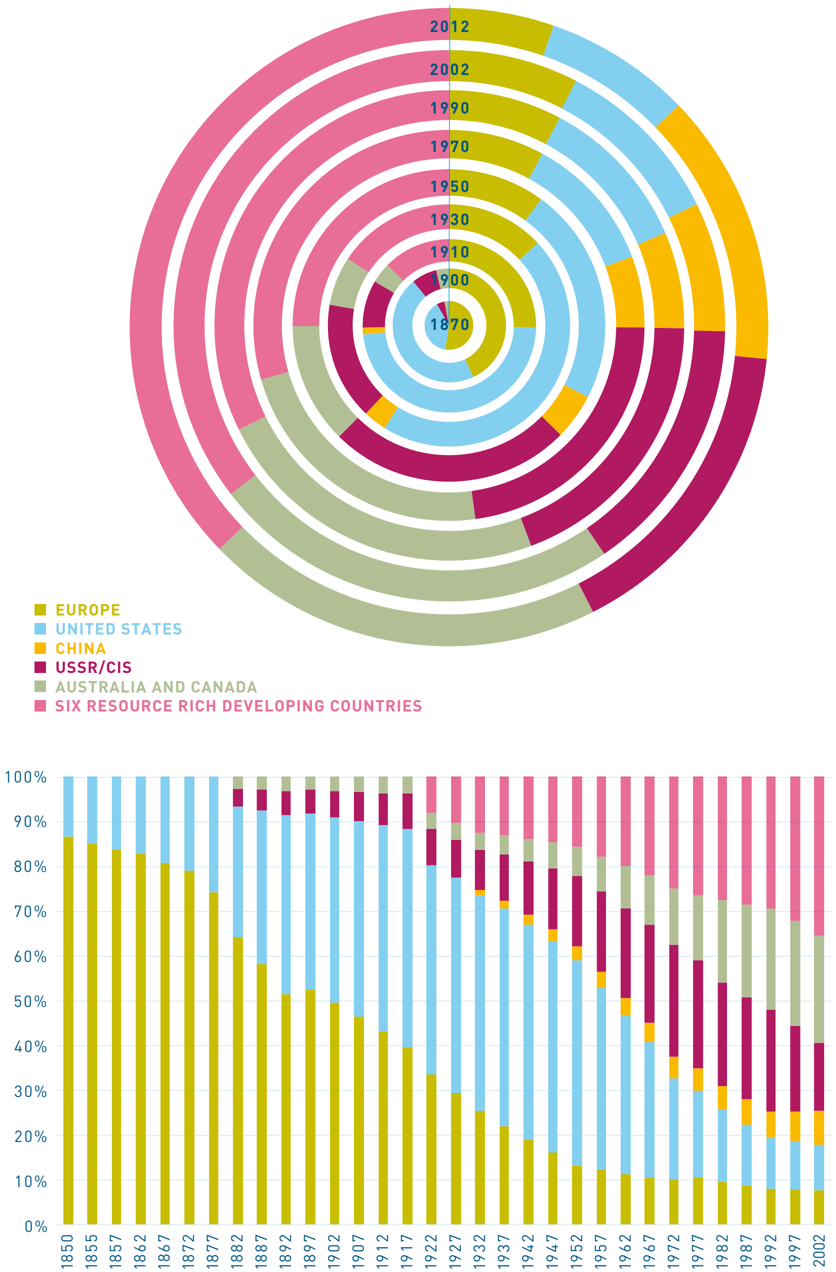


Figure 10. GEOGRAPHIC SHIFT IN PRODUCTION

3.5 Geographic shift in production

The expansion of global mineral output over the past one and a half centuries has led to a geographic shift in total mineral production. Figure 10 shows the shift in production of available resources worldwide over time.

Mining of minerals was largely concentrated in Europe and the US until the end of the 19th century. Europe and the US accounted jointly for over two-thirds of output at the turn of the century. Over the next hundred years, production diversified greatly. At the turn of the millennium, Europe and the US only produced a fifth of global mineral supply, another fifth being produced by Canada and Australia. Russia and China accounted for another fifth. Six resource rich developing countries provided a quarter of world production. The trend of production away from Western countries towards developing countries (China in particular) is continuing into the new millennium.

This shift reflects two basic trends. First, the rapid industrialisation of many parts of the world outside of the US and Western Europe over the 20th century has made industrial mining a global phenomenon. Second, the widespread depletion of economically competitive reserves in those countries that industrialized early on has pushed exploration and mining away from Western Europe and the US towards areas that were previously untouched.

Obviously, these figures being total production figures mask differences in the mining geography of individual minerals. The global geographic distribution of reserves and production of certain minerals (especially among those that are produced in relatively small quantities) is uneven, with the overwhelming share of global output generated in just a few countries.

3.6 Reserves

HCSS has gathered data on reserves for the fifteen elements and two element groups described above. The most recent reserve data for each element is shown in the series of world maps below. These maps demonstrate that the global distribution of mineral deposits that are economically exploitable with current technologies is highly asymmetric. The maps show that for most elements, global reserves are located in a handful of countries. To the extent that these countries control their national mining sector (and most do to quite a considerable extent), these reserves are controlled by these nations. Therefore, future production of these elements will to a large extent be dominated by these countries, as production can only take place where reserves are currently located. As market conditions, technology and exploration evolve and the deposits that form current reserves are progressively depleted, deposits in other countries might become profitable. Changes in the geography of production are likely to be gradual processes rather than sudden shifts.

The percentages shown in the graphs represent the currently known or stated reserves. 25%-100% means that the country has almost all reserves of a mineral. A detailed description of selected elements can be found in Annex A.

Doping agents

The global reserves of 8 doping agents, including rare earth elements, are quite diverse. The US holds significant reserves of each element in this group and has major shares of global reserves of molybdenum, zirconium and rare earths. Similarly, China (for lithium, molybdenum, tungsten and rare earths) and Australia (for hafnium, tantalum, zirconium and rare earths) hold major global reserves of a number of doping agents and have significant amounts of most others. Other important reserve holders of doping agents are Canada and Brazil (the latter particularly in the case of niobium).

Figure 11. HAFNIUM, RESERVES 2007

Figure 12. LITHIUM, RESERVES 2007

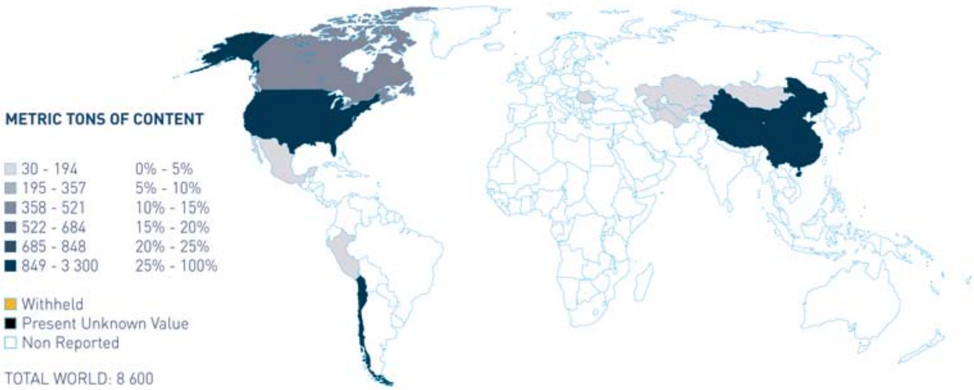


Figure 13. MOLYBDENUM, RESERVES 2007

Figure 14. NIOBIUM, RESERVES 2007

Figure 15. TANTALUM, RESERVES 2007

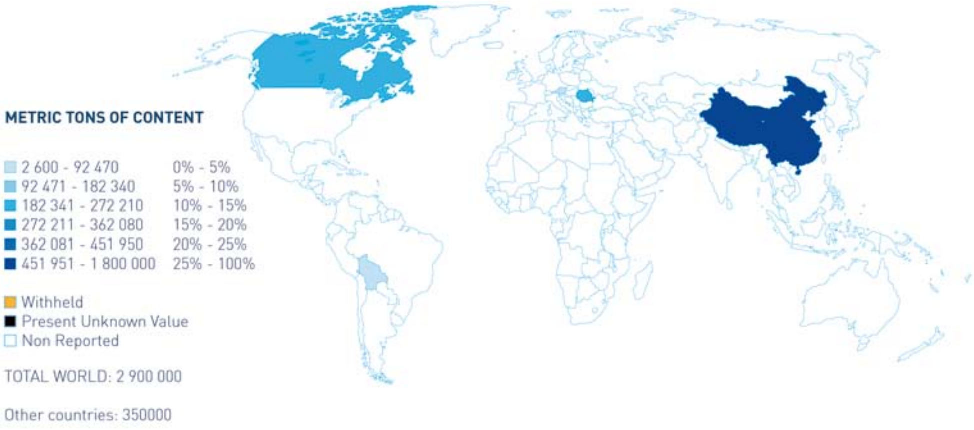


Figure 16. TUNGSTEN, RESERVES 2007

Figure 17. ZIRCONIUM, RESERVES 2007

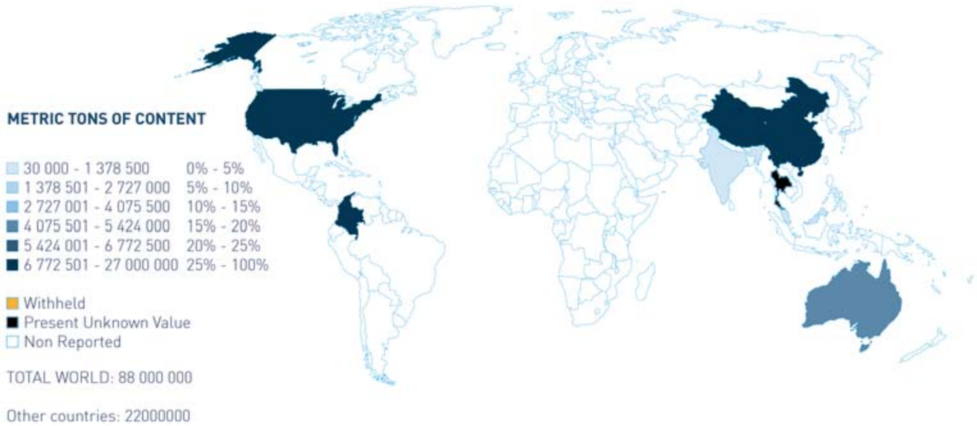


Figure 18. RARE EARTHS, RESERVES 2007

Mass consumables

Reserves of mass consumables are less concentrated than doping agents. However, China and Australia again stand out and the US also holds significant reserves of the five mass consumables that were analysed for purposes of the current study. A larger number of countries hold important reserves of one or two of these elements, among them Canada, Brazil, and Indonesia.

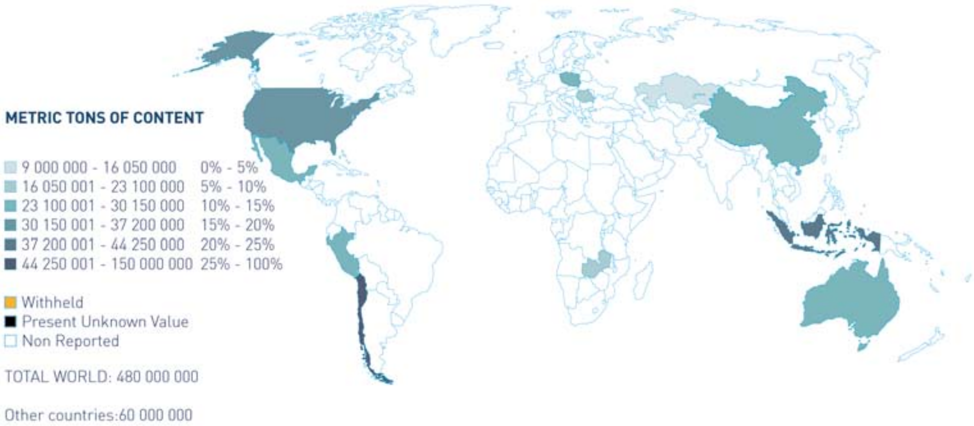


Figure 19. COPPER, RESERVES 2007

Figure 20. MANGANESE, RESERVES 2007

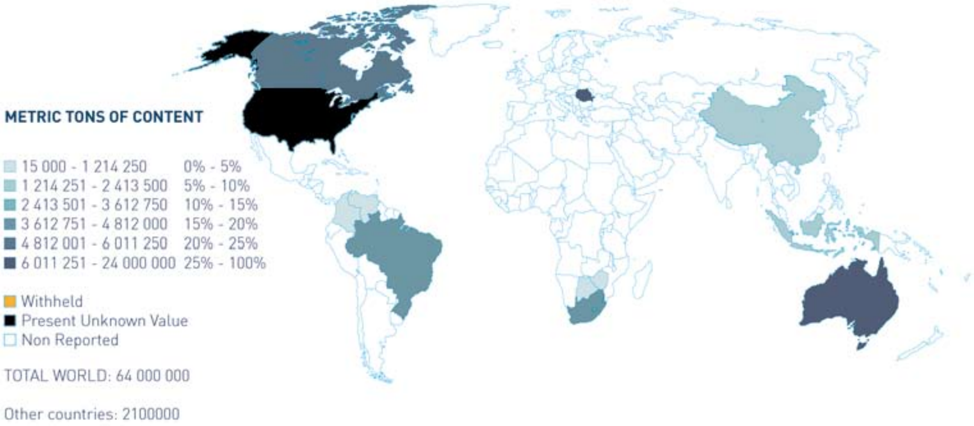


Figure 21. NICKEL, RESERVES 2007

Figure 22. TIN, RESERVE 2007

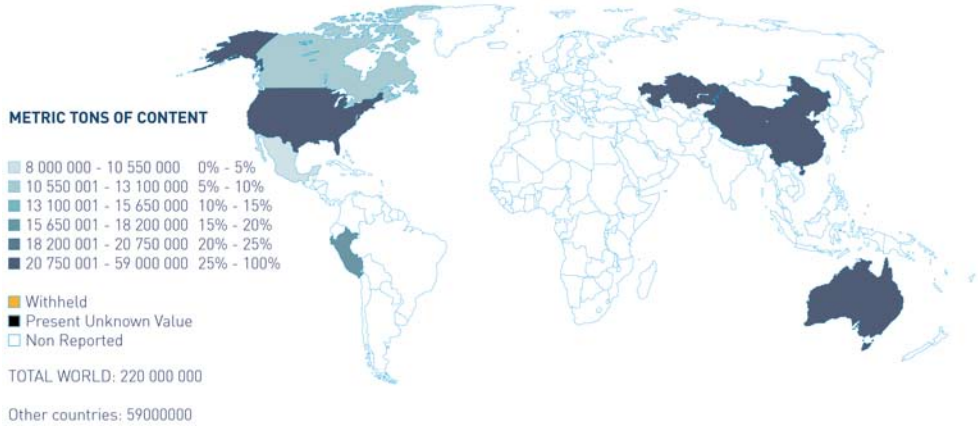


Figure 23. ZINC, RESERVES 2007

Precious metals

The reserves of platinum group metals are concentrated in South Africa, with minor profitable deposits existing in Canada and the US.

Figure 24. PLATINUM GROUP METALS, RESERVES 2007

3.6 Future developments regarding mineral scarcity

Based on these findings, what can be said about the future of mineral scarcity on the planet? Certainly, continued industrialisation of the developing world will lead to rising global demand for scarce minerals. According to the OECD, global demand for minerals is expected to double over the next 25 years. Emerging economies will consume a growing share of global mineral output and increasingly compete with western countries over access to scarce mineral reserves. Demand for metals from China has already increased 17% annually over the past five years, and accounts for more than 70% of the global demand growth for several metals such as aluminium, copper or zinc. Emerging economies are also starting to contribute significantly to the output and consumption of high-tech products. This means that the demand for rare minerals associated with such products – especially certain doping agents – is likely to increase.

Rising demand in itself will not necessarily result in debilitating levels of scarcity. Mineral demand has expanded exponentially over the 20th century and did not resulted in increasing scarcity as progress in mining technology and the geographic expansion of mining fuelled an equally fast growth in global output. For example, a century of developing increasingly high-powered and automated earth-moving technology has resulted in a 90-fold increase of the rate at which industry can displace solid rock formations.[8]

Nonetheless, there are some factors that raise serious concerns as to whether mineral production can be expanded at the same rate as in the past. Two key factors are the increasing *geological* and *geographical distance* to minerals. Past mining has concentrated on picking the 'low-hanging fruit' and depleted those resources that were of the highest quality, easiest to extract and closest to consumers. Future mining will face an increasing geological distance. This means mining deposits of lower ore grade, which are found in deeper and less accessible layers in the planet's crust.

Deposits are to be found at greater geographic distance from centres of consumption and in less accessible environments (e.g. offshore). Both trends are likely to make mining more energy intensive; and coupled with worries about

8 Atlas Copco (2005), 100 Years of Rock Drilling – The Year of the Top Hammer. http://www.atlascopco.se/us/news/productnews/rock_drill.asp.

high energy prices over the next decades, this might lead to much higher production costs. If technological progress (not only in mining but also in the energy sector) is unable to overcome geological and geographic distances, increased mineral scarcity may be the result. The complex, adaptive dynamics of global mineral markets and the uncertain development of global energy prices as well as future mining technology caution against clear-cut predictions about the future degree of mineral scarcity.

3.7 Recommended reading

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Tilton, J.E. (1999), 'The Future of Recycling.' *Resources Policy*, No. 25, pp. 197-204.

4 National mineral policies

This chapter examines the national mineral policies of several countries as well as the EU, based on a comparison of publicly available policy documents. Our analysis features short country profiles and analyses whether individual countries treat the global mineral environment as issue of national security or an issue of strategic interest. This review complements the analysis in previous chapters. It shows how states respond to (perceived) mineral scarcity as well as how individual states' policies shape it.

4.1 Research methodology

For this review, a selection of ten countries was made that represent a continuum from advanced industrialised to emerging market economies. The sample contains resource rich countries as well as resource poor countries. Selected countries may fall within one or more categories: a resource rich country that is an emerging economy, or a resource-poor advanced economy. Using this approach the following countries were selected: the United States of America, Canada, and Japan (advanced economies); the United Kingdom of Great Britain and Northern Ireland, Germany, France, and the Czech Republic (resource poor countries); the Peoples Republic of China (resource rich country); and South Africa, and India (emerging economies). For comparative reasons, our analysis also refers to EU mineral policy. The EU employs policy initiatives that complement the national policies of its member countries, but at times may differ from the policies of individual member states. The initial intention was to include the Netherlands in the benchmark as well. However, as the Netherlands does not have an official policy on minerals, it was not included in our comparative analysis.

The analysis looks at official mineral policies contained in primary policy documents. Thus, there may be a discrepancy between formal policy and informal policy and practice. After having compiled the relevant documents, the principal policy approaches taken by the individual countries were categorised according to whether countries have a national geological survey, whether policies are implemented 'top-down' or created 'bottom-up', and whether national mineral companies or private mineral companies exist. The results are shown in figure 25.

POLICY FEATURES	US	UK	FR	GE	CZ	IN	CN	CA	SA	JP	EU
NATIONAL GEO. SURVEY	X	X	X	X		X	X	X	X	X	X
LOCAL POLICY (BOTTOM-UP)		X				X					
NATIONAL POLICY (TOP-DOWN)	X			X	X		X	X	X	X	X
NATIONALISED COMPANIES						X	X			X	

Figure 25. OVERVIEW OF AVAILABLE NATIONAL MINERAL POLICIES

The policies are divided in four types of policies related to minerals: Policies based on a national geological survey; local policies (bottom-up); national policies (top-down); and policies related to nationalised mining companies.

In implementing these policies, different policy instruments are used, including: *National governance*. National governance means intra-governmental collaboration to allocate mineral resources. Control and coordination of mineral policies takes place at the national level. National governance is realised through a combination of the following factors: domestic supplier preference, direct state involvement, coherent national government policy, national transparency, good governance, public-private partnerships, national enterprise preference, and private enterprise preference.

Trade restrictions. Trade restrictions are government-imposed restrictions on the free international exchange of goods and services. In the mineral realm, trade restrictions consist of tariffs, export restrictions, import restrictions, direct and export subsidies, layered exchange rates, administrative barriers and anti-dumping policies.

Technological development. Technological development refers to efforts of governments and collaboration between governments and industry to enhance technological development related to mineral extraction. Technological development may be realized through identification of renewable energy and recycling opportunities, examining substitution possibilities for critical minerals, government-led Research and Development, and domestic capacity and knowledge-base improvement.

Pro-active acquisition. Pro-active acquisition refers to ensuring the continuity of critical mineral supply through explicit safeguarding methods. Pro-active acquisition is realised through identifying critical minerals, stockpiling, international strategic partnerships and foreign direct investments.

Development cooperation. Development cooperation refers to the international transfer of public funds in the form of loans or grants, through bilateral aid or through non-governmental organisations or multilateral agencies (multilateral aid), with the aim of supporting and promoting economic, social and political development in other countries. The aim is to support and promote economic, social and political development in receiving countries for the benefit of the sending countries in relation to the mineral industry; so called infrastructure-for-minerals deals are an example of mineral-related development cooperation.
Global governance. Global governance means political interaction among international actors, through which collective interests are articulated globally, rights and obligations established, and differences resolved. In the context of mineral policies global governance refers to efforts to liberalise or regulate the global mineral market and international collaborative governance of mineral resources. (For more details see Annex C)

TYPE OF POLICY	POLICY INSTRUMENT
NATIONAL GOVERNANCE	Domestic Supplier, Preference, Direct State Involvement, National Coherent Government Policy, National Transparency, National Good Governance, Public-Private Partnerships, National Enterprise Preference, Private Enterprise Preference
TRADE RESTRICTIONS	Tariffs, Import Restrictions, Export Restrictions, Direct Subsidies, Export Subsidies, Layered Exchange Rates, Administrative Barriers, (Anti-)Dumping Policies
TECHNOLOGY ADVANCEMENT	Renewable Energy, Recycling, Substitutes, Research & Development, Domestic Capacity Improvement, Knowledge Base Improvement
PRO-ACTIVE ACQUISITION	Identification Critical Minerals, Stockpiling Minerals, International Strategic Partnerships, Foreign Direct Investment
DEVELOPMENT COOPERATION	Development Aid, Transparency, Good Governance
GLOBAL GOVERNANCE	Liberalisation World Market, Collaborative Governance

Figure 26. POLICY CATEGORISATION AND VARIABLES

4.2 Individual countries and EU policy profiles

The following sections discuss individual country and EU profiles. (see also Annex B).

United States of America

The United States (US) has a long history of mineral policy making. Traditionally, US policy is focused on developing domestic mining capacities. Already since World War I policies are explicitly designed to secure the supply of critical minerals. The central US government policy on minerals is articulated in the National Materials and Minerals Policy, Research and Development Act of 1980, complemented by 2009 *Reconfiguration of the National Defence Stockpile Report to Congress*. The importance of a national mineral policy is underlined by Congress declaring that 'the availability of materials is essential for national security, economic well-being, and industrial production.[9] The two documents describe the focus of US mineral policy in the context of national security, and use several policy instruments including domestic preference, R&D and strategic stockpiling of minerals.

US policy emphasises national governance measures, such as a coherent national government policy, harmonizing and guiding local state policies, public-private partnerships, a strong preference for domestic suppliers, and actively investing in critical mineral production. Explicit trade restrictions are mentioned with regard to defence acquisition, where the US 'can, and does, formally establish restrictions within the Defence Federal Acquisition Regulation Supplement on the use of foreign products for certain defence applications, when necessary, to ensure the survival of domestic suppliers required to sustain military readiness.[10]' There is also a strong focus on technological advancement promoting domestic innovation, recycling and domestic capacity improvements. This is linked to pro-active acquisition of critical minerals through stockpiling policies and international, bilateral, strategic partnerships.

Japan

National mineral policy in Japan is laid down in a document entitled *Guidelines for Securing Natural Resources*. Japanese mineral policy primarily aims at securing a stable supply of energy resources. This is done in tandem with other key policies on national economic and fiscal management and energy policy. In light of Japan's scarce domestic mineral reserves, the policy seeks to support key resource acquisition projects, employ active mineral diplomacy, and link acquisition projects to economic cooperation.

Japanese mineral policy favours direct state involvement in mineral policies. When Japanese mining companies acquire exploration licenses abroad, this

9 United States Congress (1980), National Materials and Minerals Policy, Research and Development Act, Title 30, Chapter 28, Section 1601.

10 Defense National Stockpile Center (2009), Reconfiguration of the National Defense Stockpile (NDS) Report to Congress, p.16.

should take place in the context of public-private negotiations and partnerships.[11] Exploration itself remains under the control of private mining companies. Mineral policy emphasises coherence and inter-governmental cooperation. The policy does not address technological development or trade restrictions, except in the form of direct subsidies. It does however focus on pro-active acquisitions through foreign direct investments and international strategic partnerships: '[G]overnment support for resource acquisition projects is inseparably tied to the establishment of comprehensive and reciprocal bilateral relations and the promotion of multilateral diplomacy'.[12] Key active acquisitions policies are defined in projects to acquire mining exploration or development interests, as well as in projects related to long-term supply contracts. In line with Japanese mineral policy, official development assistance (ODA) seeks to build sustainable relationships with resource producing countries, through supporting resource development projects, both in developing countries as well as in emerging market economies. In order to ensure the secure supply of mineral resources from the international mineral market, Japanese policy also encourages countries to act in accordance with multi- and bilateral rules and regulations.

The United Kingdom and Northern Ireland

The national policy regarding minerals in the United Kingdom (UK) is laid down in the June 2008 Treasury Report on *Global Commodities: a long term vision for stable, secure and sustainable global markets*. The document provides comprehensive national policies for all sorts of commodities, with a short section devoted to minerals. Focusing on the increasing scarcity of a broad spectrum of commodities, the UK advocates policies which will stabilise tight global markets and which will prevent the escalation of conflicts over scarce resources.

The policy approach and instruments that are mentioned in the document emphasize technology development, R&D and the development of renewable

11 Private negotiations refer to negotiations where Japanese private enterprises directly negotiate with foreign private enterprises, however under the facilitation of Japanese government officials. Public-private negotiations refer to negotiations where the Japanese government negotiates either on behalf of private enterprise or on behalf of public enterprises and public-private partnerships.

12 Japanese Ministry of Economy, Trade and Industry (2008), Guidelines for Securing Natural Resources (Provisional Translation), p. 2.

resources through public-private partnerships. The document does not mention trade restrictions or pro-active acquisition policies. On the contrary it states that 'countries should resist distortions and protectionist measures, aimed at tackling immediate price shocks domestically, but which exacerbate price increases internationally'.[13] Moreover, the UK mineral policy focuses strongly on development cooperation, in particular transparency measures and good governance, and encourages cooperative global governance in order to create a stable economic system.

Germany

Two important documents describe the mineral policy of Germany: the 2007 *Elemente einer Rohstoffstrategie der Bundesregierung* and the 2008 *Zwischenbilanz der Rohstoffaktivitäten der Bundesregierung (Schwerpunkt nichtenergetische Rohstoffe)* both issued by the Ministry of Economy and Technology. The German mineral policy approach and its instruments strongly focus on innovative measures, multilateral initiatives and aid to resource rich development countries.

Germany takes a comprehensive policy approach combining coherent national policies with public private partnerships. Trade restrictions are not explicitly mentioned. Technological development is a primary policy element, focussed on recycling, substitutes and renewable resources, as well as on domestic capacity and knowledge base improvement. While pro-active acquisition initially was not part of German policy, the 2008 policy refers to strategic partnerships and foreign direct investments: 'Durch Förderung neuer Bergbauprojekte in diesen Bereichen wird die Rohstoffverfügbarkeit erhöht und so ein Beitrag zur Entspannung auf den Weltrohstoffmärkten geleistet, wovon auch die deutsche Wirtschaft profitiert'.[14] Development cooperation and global governance form an integral part of the German mineral policy, with an emphasis on multilateral cooperation and coordination within the EU framework. 'Nach Auffassung der Bundes-regierung geht es nicht darum, eine staatliche Rohstoffsicherung auf EU-Ebene anzustreben, sondern darum, dass die EU bei Fragen der Rohstoffaußenpolitik mit einer Stimme spricht'.[15]

13 Her Majesty's Treasury (2009), Global Commodities: Long-Term Vision for Stable, Secure and Sustainable Global Markets, p. 61.

14 Die Bundesregierung (2008), Zwischenbilanz der Rohstoffaktivitäten der Bundesregierung (Schwerpunkt nichtenergetische Rohstoffe), p. 6.

15 Die Bundesregierung (2007), Elemente einer Rohstoffstrategie der Bundesregierung, p. 13.

France

French mineral policy is elaborated in the 2009 *Stratégie Nationale de recherché et d'innovation, rapport de groupe de travail resources naturelles*. The French policy is one of the least comprehensive policies found in the sample. Although the document acknowledges a possible future scarcity problem it only mentions innovation related policy measures in this regard.

The French advocate a national coherent government policy. There is no mention of trade restrictions. French policy emphasizes the need for renewable resources, the search for substitutes and related R&D and strives to 'diversifier les resources naturelles en favorisant le recours aux resources renouvelables par le développement d'innovations technologiques et organisationnelles'.[16] The French government focuses on international rules and regulations on mineral trade through global governance and sees an important role for the European Union in this regard.

India

The National Policy on minerals in India is summarised in the *National Minerals Policy 2008 For Non-fuel and Non-coal Minerals*. Focusing on the country's mineral resources extraction potential and its role in the country's overall economic development, India targets internal capacity building, geological mapping, sustainable mining, the stimulation of R&D and the improvement of industry investment structures. Indian national policy has a pronounced national governance focus, primarily centred on coherent national minerals and minerals related policies, national transparency, good governance, and, to a lesser extent, public-private partnerships and private enterprises. The Geological Survey of India is 'responsible for drawing up action oriented plans towards [geological mapping and regional mineral resources assessment] in close cooperation with all other agencies engaged in this task'.[17] The policy emphasises technological development , research and development as well as domestic capacity and knowledge base improvement: 'To enable the use of state of the art exploration techniques, scientific mining and optimal use of minerals through ore dressing and beneficiation technologies it is necessary not only to promote research and

16 Ministère de l'Enseignement Supérieur et de la Recherche (2009), Stratégie Nationale de Recherche et d'Innovation, p. 4.

17 Government of India Ministry of Mines (2008), India's National Mineral Policy 2008 (For Non-Fuel and Non-Coal Minerals), p. 4.

development in minerals but to simultaneously establish appropriate educational and training facilities for human resources development to meet the manpower requirements of the mineral industry'.[18] The policy does not refer to trade regulations but talks of pro-active acquisition through identification of critical minerals. The policy does not refer to development cooperation, nor to global governance measures.

People's Republic of China

The national mineral policy of China is laid down in the governmental White Paper entitled *China's Policy on Mineral Resources*. Since China has a broad national resource base as well as a need for imported mineral resources, China's policy is quite diversified. Focusing on domestic policies, innovation and international acquisition, the Chinese white paper provides a comprehensive policy.
China has a strong national governance focus emphasising domestic supplier preference and the need for direct state involvement to supervise the mining industry, in combination with strong public private partnerships.
Simultaneously, China implements policies to further national transparency.
Technological development focus on domestic capacity and knowledge improvement combined with research into substitute minerals and technical R&D. Through pro-active acquisition policies '[t]he Chinese government encourages domestic enterprises to take part in international cooperation in the sphere of mineral resources, and in exploration, exploitation and utilisation of foreign mineral resources'.[19] Stockpiling of strategic minerals, international strategic partnerships and strategic foreign direct investment are the favoured instruments to secure supply. The White Paper does not mention development cooperation but does refer to global governance: 'China will, as usual, take an active part in international cooperation for the development of resources and environment protection, and join hands with all other countries in the world in advancing boldly to achieve the sustainable development of human society'.[20]

Canada

The national policy on minerals in Canada is laid down in *The Minerals and Metals Policy of the Government of Canada: Partnerships for Sustainable Development*.
The policy identifies challenges related to the natural environment, globalisation

18 Ibid., p. 3.

19 Chinese State Council (2003), China's Policy on Mineral Resources, p. 1.

20 Ibid., p. 18.

and competitive markets, governmental efficiency, and sustainable development. It focuses on national governmental policy, the encouragement of social development factors and international rules and regulations. Canadian mineral policy favours coherent policy at the national level, national transparency, good governance, public-private partnerships, and a preference for national enterprises. Canadian policy advocates technological development in the area of renewable energy and recycling, as well as R&D. The policy does not refer to trade restrictions in order to guarantee a secure supply of minerals.

Quite the contrary, it states that 'all countries must work together to ensure that a positive investment climate is maintained'.[21] Pro-active acquisition measures are identified through international strategic partnerships. Notably, the policy focuses on development cooperation through development aid, the encouragement of transparency and good governance. Canadian mineral policy calls for liberalizing world markets and global governance where 'the Government affirms its commitment, through bilateral and regional initiatives, to promote the sustainable development of minerals and metals and to develop, where resources permit, partnerships with countries that share our views and concerns'.[22]

South Africa

The South African national policy on minerals is elaborated in *A Minerals and Mining Policy for South Africa*. The policy is divided into six parts: business climate and mineral development, which seeks to improve the investment climate in the mining and refining sector; participation in ownership and management; people issues, which primarily targets racial inequality, health and safety and industrial relations; environmental management; regional cooperation; and governance. Referring to South Africa's extensive and diverse resource base, the policy focuses on national and international governmental action as well as development of technology.

South Africa's mineral policy explicitly advocates national government measures such as direct state involvement, national transparency, good governance, and public-private partnerships in combination with an increased national enterprise preference. Municipalities and R&D institutions are encouraged to seek public-

21 Minister of Public Works and Government Services Canada (1996), The Minerals and Metals Policy of the Government of Canada: Partnerships for Sustainable Development, p. 8.

22 Ibid., p. 24.

private partnerships, however '[...] in terms of the Constitution the State is bound to take legislative and other measures to enable citizens to gain access to rights in land on an equitable basis. [...] Government's long-term objective is for all mineral rights to vest in the State for the benefit of and on behalf of all the people of South Africa'.[23] With regards to technological development, South African policy focuses on recycling, and 'efforts [that are] directed to develop solutions in exploration, mining, processing, beneficiation and environmental conservation and rehabilitation of the environment as well as to satisfy the needs of global customers [...]'.[24] The policy does not cover trade restrictions, pro-active acquisitions and development cooperation.

Czech Republic

The national policy on minerals in the Czech Republic is stated in a policy document entitled *The Raw Materials Policy of the Czech Republic in the Field of Mineral Materials and Their Resources*, issued jointly by the Ministry of Industry and Trade and the Ministry of Environment. The policy is a listing of all activities through which the Czech state exerts its influence on the mapping, extraction and utilisation of domestic raw material resources and the acquisition of raw materials abroad to secure domestic supply. Referring to the Czech Republic's rather poor raw material predisposition, the policy calls for wide cooperation and a well-developed and fair global raw materials market as well as a restructuring of the mining industry on a national level.

The Czech Republic's national policy does not explicitly address national governance measures. It articulates a need for technological development through new legislation, on waste management and recycling, as well as R&D programs and business support programs. Recycling encouraged in order to achieve energy saving, reduce environmental burdens, contribute to foreign trade, and reduce dependency on primary resources. The policy does not refer to trade restrictions, but as the country's resources are negligible compared to domestic consumption, it declares the need for pro-active acquisition through operations abroad and strategic memberships in specific international organisations: 'By means of tools applied, the pursued raw material policy will strive to create operatively such a space, with respect to all time horizons,

23 South African Government (1998), A Minerals and Mining Policy for South Africa, p. 18.

24 Ibid., p. 31.

which would be necessary in particular for utilisation of restricted raw material resources being of economic importance'.[25] The Czech government aims at direct government involvement in implementing its minerals policy. The policy highlights global governance through liberalisation efforts in global markets and encourages implementation of international cooperative governance.

European Union

The European Union (EU) does not have an official policy regarding mineral scarcity yet. It is however on its way enacting such a policy under that which is called *The Raw Materials Initiative – Meeting Our Critical Needs for Growth and Jobs in Europe*.[26] Though not being a direct policy in itself, the initiative does stipulate direct measures of action in order to secure a supply of [scarce] minerals. The Commission is to report to the Council in 2010 on the implementation of the initiative. Therefore the initiative has been included in the analysis and treated as a policy, albeit categorised based on future implementation.

The initiative recognises that raw materials are essential for the sustainable functioning of modern societies and that 'access to and affordability of mineral raw materials are crucial for the sound functioning of the EU's economy'.[27] The initiative furthermore states that the EU faces fundamental changes on the global mineral markets, mainly in availability and price developments for raw materials and in new industrial strategies and risks of dysfunctional global markets. It also recognises that '[the] challenges are likely to persist, or even increase'.[28] As such, it is evident that the EU sees both pro-active acquisitions through FDI and international strategic partnerships and trade restrictive measures as necessary. However, by at the same time emphasising the need for global governance measures, it is likewise clear that EU rather strives for an open minerals market. The initiative suggests an integrated policy which must firstly ensure access to raw materials from international markets under the same conditions as other

25 Ministry of Industry and Trade and Ministry of Environment of the Czech Republic (1999), The Raw Material Policy of the Czech Republic in the Field of Mineral Materials and Their Resources, pp. 30-31.

26 Commission of the European Communities (2008), The Raw Materials Initiative – Meeting Our Critical Needs for Growth and Jobs in Europe. Communication from the Commission to the European Parliament and the Council.

27 Ibid., p. 2.

28 Ibid., p. 12.

industrial competitors. In this the EU should pursue active raw materials diplomacy, engage in strategic partnerships and international cooperation, rid EU trade and regulatory policy from possible administrative barriers, and promote global good governance, transparency and budget support. The policy emphasises coherence and inter-governmental cooperation. Secondly the policy must set the right framework conditions within the EU in order to foster a sustainable supply. This requires an improved knowledge base of mineral deposits, networking between national geological surveys, promotion of research projects and cooperation between universities, geological surveys and industry. Thirdly, the policy must be able to boost resource efficiency and recycling in order to reduce consumption of primary raw materials and decrease import dependence. The policy should therefore give further impetus to resource efficiency and eco-innovative production processes, recycling of secondary raw materials and the implementation of the Basel Convention.

4.3 Findings

All policy documents were evaluated using the taxonomy for policy instruments developed above. In the graph below, X indicates that the respective policy instrument was explicitly mentioned in the policy documents examined. To certify results, analysts independently coded the data and discussed in group meetings in case of disagreements. An overview of the results is presented in figure 27.

VARIABLES	CAT.*	US	CA	CN	JP	GB	FR	GE	CZ	EU	IN	SA
Domestic supplier preference	NG	X		X		X						
Direct state involvement	NG	X		X	X							X
Coherent government policy	NG	X	X		X	X	X	X		X	X	
National good governance	NG		X	X							X	X
National transparency	NG		X	X							X	X
Public-Private partnerships	NG	X			X	X		X			X	X
Nationalised enterprises	NG		X									X
Privatised enterprises	NG								X		X	
Tariffs	TR											
Import restrictions	TR									X		
Export restrictions	TR											
Direct subsidies	TR			X	X							
Export subsidies	TR											
Exchange rates	TR											
Administrative barriers	TR	X		X								
Anti-dumping measures	TR											
Renewable energy	TA		X	X		X	X	X	X	X		
Recycling	TA		X	X		X		X	X	X		X
Substitutes	TA	X				X	X	X		X		
Research & Development	TA	X	X	X		X	X	X	X	X	X	X
Dom. capacity improvement	TA	X		X				X	X	X	X	
Knowledge base improvement	TA	X						X	X	X	X	
Identification critical minerals	PA	X		X		X						
Stockpiling critical minerals	PA	X		X		X						
Int. strategic partnerships	PA	X	X	X	X			X		X		
Foreign direct investments	PA			X	X			X		X	X	
Development aid	DC		X		X	X		X		X		
Transparency	DC		X			X		X		X		
Good governance	DC		X			X		X		X		
Liberalisation world market	GG		X		X	X		X	X	X		X
Global governance	GG		X	X	X	X	X	X	X	X		X

* POLICY CHARACTERISTICS:

NG = National Governance
TR = Trade Restrictions
TA = Technological Advancement
PA = Pro-Active Acquisition
DC = Development Cooperation
GG = Global Governance

Figure 27. PRESENCE OF VARIABLES IN NATIONAL POLICY

The comparison depicted here gives a comprehensive overview of the policy instruments deployed by the countries under review to deal with the global mineral challenge.[29]

The following section discusses the national policies in the light of the six policy approaches defined above: national governance, trade restrictions, technological advancement, pro-active acquisitions, development cooperation, and global governance. For each policy approach, different countries' policies are mapped on a scale.

National governance

Our analysis shows that the national governance approach relies on four key policy instruments. First, mineral policies of the United States, China and Japan rely heavily on direct state involvement to secure the availability and steady supply of minerals. The Government of Japan, for example, participates both in private and public-private negotiations with regard to investments in foreign mineral enterprises. The US, on the other hand, buys critical minerals and sells these to national industries. China and the US use domestic supplier preference as a mineral policy instrument as well, to ensure the continuity of national strategic capacities.

Second, nearly all countries reviewed mention the need for a coherent national government policy, seeking to establish a 'whole of government approach' with regard to minerals. Germany, for example, pursues active cooperation between the national geological survey, the mining industries, leading producing industries, ministries, departments and local and national governmental agencies, in order to create a single comprehensive national policy approach in ensuring mineral availability.

Third, public-private partnerships are used by almost all countries as the policy instrument of choice. These partnerships are used to pool resources, bundle forces (for example through the combination of governmental diplomatic contacts and private subject matter expertise), in order to gain a better position

29 It is noticeable that China does not indicate for export restrictions. Export restrictions are not mentioned in the formal policy documents analysed by HCSS. However, other sources (e.g. United States Geological Survey) indicate that China implements export restrictions.

in the mineral market and improve access to particularly scarce minerals. India is a particularly good example here, encouraging joint public private participation in developing viable economic and political framework as well as public private partnerships to develop a working infrastructure.

Fourth, emerging economies and developing countries – China, India, South Africa and Brazil – emphasize national transparency and good governance measures. These countries are setting up legal frameworks regulating the mineral industry to enhance mineral extraction, usage and trade. Its primary purpose is to strengthen governmental oversight, national control over (possible) mineral gains and to secure a steady supply of minerals.

Plotting the ten countries examined on a scale from a minor to a strong role for the national government in mineral policies, the following picture emerges:

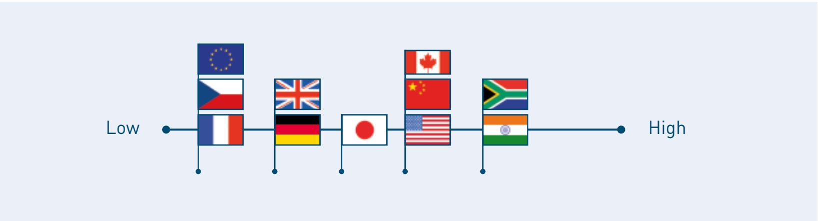


Figure 28. NATIONAL GOVERNANCE

Trade restrictions

Almost none of the national policies reviewed refer to trade restrictions as the policy instrument of choice. The EU is an exception. It explicitly outlines the implementation of import restrictions as policy response to *any* trade restrictions put in place by trading partners. Though not stated policy, others also use export restrictions in practice. The EU recently reported that a recent rise in global commodities prices lead to a proliferation of export restrictions - at least 450- for commodities and raw materials including metals, metals scrap and chemicals. The report mentioned in particular China, India and Russia who impose export duties reaching up to 120 percent on certain minerals. The report concluded that mainly developing countries use export taxes to raise revenue and encourage domestic processing of raw materials.[30] Hence, a lack of reference to trade restrictive measures may not accurately reflect actual policy. Therefore, the mapping of China, India and Russia on the 'low' end of the scale may not 'make sense' when taking recent political, social and economic developments into account, even if it reflects formal policy. Other reports also show that most countries use trade restrictions of various kinds.[31] Japan and China use of direct subsidies may be explained by the fact that both countries have nationalised most mineral companies. The mineral policies of the US and China both mention the usage of administrative barriers. These non-tariff barriers involve rules and regulations that seek to protect the national mineral extraction indus-try. As a result, it is much harder for foreign companies, if not impossible, to invest and gain a foothold in the national mineral extraction industry in these countries.

When plotting the formal policies on a scale from little use of trade restrictions to regular use, the following picture emerges.

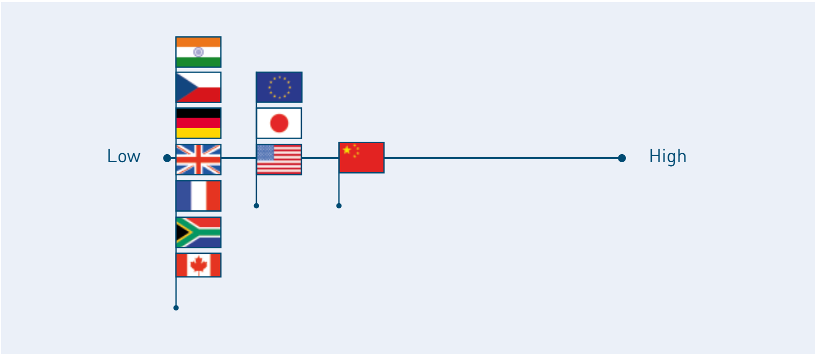


Figure 29. TRADE RESTRICTIONS

30 International Centre for Trade and Sustainable Development (2008), 'EU Warns Against Trade Restrictions on Raw Materials.' Bridges Weekly Trade News Digest, Vol. 12, No. 32. See also 'World Faces Hi-Tech Crunch as China Eyes Ban on Rare Metal Exports.' Daily Telegraph, 24 August, 2009, for further commentary on Chinese export restrictions.

31 See amongst others Office of the United States Trade Representative (2005), National Trade Estimate Report on Foreign Trade Barriers. Also see European Commission (2009), United States Barriers to Trade and Investment Report for 2008, for reference on US trade restrictions.

Technological development

All national policies examined emphasise the role of technology in coping with mineral availability. Investment in research and development (R&D) as well as encouraging technological innovation in the field of mineral usage, extraction and processing, feature prominently among the policy instruments of choice. Although Japan does not mention R&D in its policy document, it is evident that, as a highly developed industrial country, Japan does have extensive R&D policies.[32]

It is remarkable that the US does not refer to renewable energy or substitution policies. On the whole, research into substitution minerals is rarely pursued. Almost all countries stimulate knowledge base improvement. India recently set up a National Geological Survey and the European Union initiated a European Geological Survey, both indicating efforts to centralise available information and identify minerals, extraction and development possibilities.

Resource rich countries, predominantly the US and China, emphasize domestic capacity improvement, mostly in order to decrease dependency on foreign mineral sources or, in the case of developing countries such as South Africa, to optimise output and profits.

The EU has initiated a wide array of policy initiatives in the area of technological development, emphasising technological policy options as well as intra-European resource- and knowledge base optimization with regard to minerals. For example, the EU finances the 7th Framework Programme (FP7); the European Technology Platform on Sustainable Mineral Resources -which focuses on innovative exploration technologies to identify deeply located onshore and offshore resources and new extraction technologies; and the Waterborne Technology platform which will undertake research for technologies that allow

32 The Japanese mining policy should be seen as complementary with further policy implementation and government strategy as presented by Japan Oil, Gas and Metals National Corporation (JOGMEC). See JOGMEC (2007), Technology Development and Technical Support (Metals), http://www.jogmec.go.jp/english/activities/technology_metal/index.html and JOGMEC (2007), Gathering/Providing Information (Metals), http://www.jogmec.go.jp/english/activities/gathering_metal/index.html for further information of governmental strategy on technology development and the gathering and providing of information.

for a future sustainable exploitation of the seabed.[33] EU policy initiatives consider minerals as 'essential for the sustainable functioning of modern societies'.[34] The EU 'has many raw material deposits [but that] their exploration and extraction are facing increased competition for different land uses and a highly regulated environment, as well as technological limitations in access to mineral deposits'.[35] When plotted on a scale from general to specific technological development, the following picture emerges:

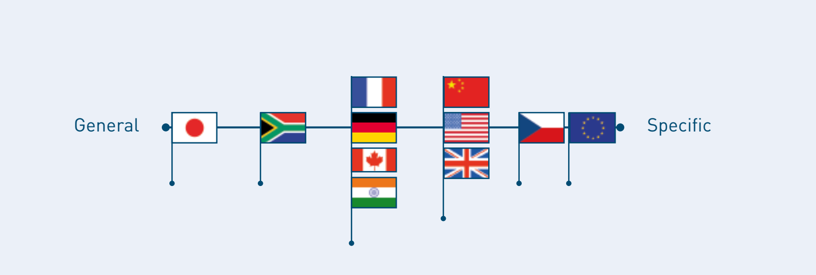


Figure 30. TECHNOLOGICAL DEVELOPMENT

Pro-active acquisition

A number of national policies explicitly call for pro-active acquisition, while other countries do not have any pro-active acquisition policies in place. The US and China are active across the entire spectrum of pro-active acquisition policies and actively identify mineral reserves, stockpile critical minerals, establish international strategic partnerships and actively pursue opportunities for foreign direct investment. This underscores the importance the US and China attach to the gathering and safeguarding of critical and (perceived) scarce minerals. Japan's policy includes strategic international partnerships and foreign

33 Commission of the European Communities (2008).

34 Ibid.

35 Ibid., p. 2.

direct investment. However, additional official documents indicate that Japan also actively pursues stockpiling strategies and identifies critical minerals.[36]

The EU mineral policy covers all dimensions of pro-active acquisition, except for stockpiling. In light of the crude oil and petroleum stockpiling directive – which imposes an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products covering the Member States energy needs for 90 days – this might change in the future.[37] The policies of individual European countries do not refer to pro-active acquisition policies for minerals. Considering the fact that these countries are largely dependent on import of most minerals, this is striking.

Most countries apply international (bilateral) strategic partnerships, a policy instrument that may be described as a sort of 'mineral diplomacy.' China, for example, has established several strategic partnerships with resource rich African countries and Brazil[38]; India has established strategic bilateral partnerships with both Kazakhstan[39] and South Africa.[40]

Plotting the national policies on scale from the use of few to many policy instruments associated with pro-active acquisition, the following picture emerges:

36 See for example JOGMEC (2007), Rare Metals Stockpiling Program, http://www.jogmec.go.jp/english/activities/stockpiling_metal/raremetals.html. For an international overview on foreign direct investment in natural resources, see United Nations Conference on Trade and Development (2007), Report of the Expert Meeting on Foreign Direct Investment in Natural Resources.

37 Council of the European Union (2006), Council Directive 2006/67/EC, imposes an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products covering the Member States energy needs for 90 days.

38 'Brazil's President in China for Talks Cementing Partnership, Securing 13 Deals,' China View, 19 May, 2009.

39 'India & Kazakhstan Established Strategic Partnership in Minerals, Oil and Gas,' DARE, 24 January, 2009. http://www.dare.co.in/news/others/india-a-kazakhastan-established-strategic-partnership-in-minerals-oil-and-gas.htm

40 'South Africa, India Strengthen Strategic Partnership,' Emerging Minds, 21 February, 2008. http://emergingminds.org/South-Africa-India-strengthen-strategic-partnership.html

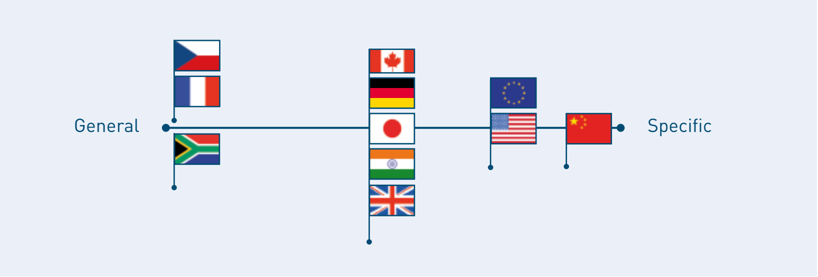


Figure 31. PRO-ACTIVE ACQUISITION

Development cooperation

With regards to development cooperation, two findings emerge. First, it is noticeable that primarily western countries rely on development aid as a policy instrument to advance their respective mineral strategies. Development cooperation is predominantly used to foster good governance, enhance transparency and create reliable government structures, regulations and policies in resource-rich developing countries.

The US and China's mineral policies do not indicate that development cooperation is used in the context of mineral policies. Other sources, however, show both countries do use development aid as a policy instrument.[41]

41 See for example Hills, A. (2006), 'Trojan Horses? USAID, Counter-Terrorism and Africa's Police.' Third World Quarterly, Vol. 27, No. 4, pp. 629-643.

When plotted on a scale from no use to frequent use of development cooperation as a policy tool to pursue mineral policies, the following picture emerges:

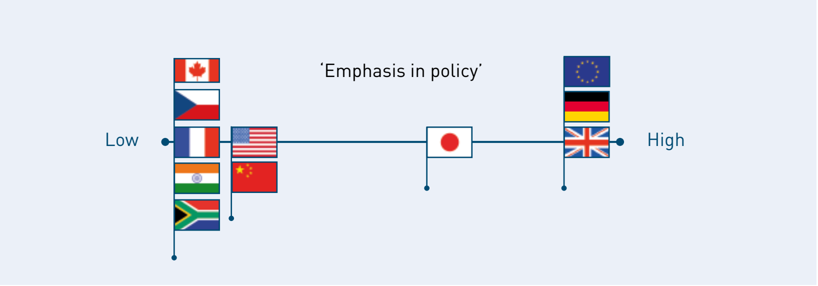


Figure 32. DEVELOPMENT COOPERATION

Global governance

The mineral policies of the countries under review often discuss global governance and the creation of international regulatory frameworks, in conjunction with free trade agreements and organisations such as the WTO, IMF and NAFTA. Both industry and resource based countries' mineral policies seek to promote a liberalisation of the world market (and as a consequence possibly also a liberalisation of the national market) in order to foster security through market stability and predictability. This guarantees unrestricted market access, and secures the availability and supply of minerals. This policy approach is especially noticeable among European countries.

When plotted on a scale from low emphasis on global governance to strong emphasis, the following scale of national policies emerges:

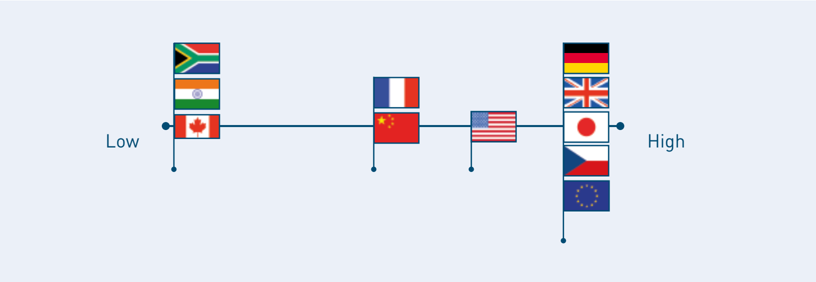


Figure 33. GLOBAL GOVERNANCE

4.5 Trends in mineral policies

Based on our analysis of national mineral policies a number of conclusions can be drawn as to how individual countries view the mineral environment. Is mineral scarcity a predominantly technological problem, a trade issue or a national security or strategic priority? Based on our analysis, two trends can be discerned.

I. Mineral scarcity is a technological issue

Mineral supply is primarily considered a technological issue. Securing mineral supply is framed in technological terms and technological innovation is seen as key to doing so. All countries under review have policies in place that emphasise the importance of technological development, i.e., how to enhance national knowledge and domestic capacity and expand research and development. The majority of mineral policies, with the exception of the US, China and Japan, do not focus on the issue of scarcity and security of supply. Instead, they concentrate on technological advancement and environmental sustainability.

II. Mineral supply is a security issue

However, driven by increasing concerns over securing supply of raw materials and growing awareness of the need to manage all finite resources in a prudent and responsible manner, policy makers and regulators are beginning to appreciate the importance of safeguarding access to mineral resources.[42] Countries that view minerals as a security issue typically focus on the identification and stockpiling of critical minerals. By designating minerals as critical for national security and development, policies are designed to control mineral flow and secure supply of critical minerals. State resources are used to gain access or acquire these critical minerals.

Our review identified a number of policy measures that are particularly relevant in securing the supply of minerals. These policies can be used at a national and an international level. These policy measures include:

- *Securing mineral supply at the national level*. Direct state involvement is used by a number of countries (the US, China, and Japan) to strengthen governmental grip on the supply of minerals. The creation of a system of national overview – who does/needs what and when? – is a typical first step in this endeavour. Strengthening ties with mineral industries, and establishing public-private partnerships, is instrumental in safeguarding mineral supply.
- *Increasing domestic capacity*, particularly mapping, extracting and refining minerals is an important aspect of securing mineral supply at the national level, especially for countries such as the US, Japan, China and the EU as a supranational organisation. By mapping domestic dependence on foreign minerals, these dependencies can be reduced. In this case we see a preference towards domestically extracted minerals and towards preventing national mining endeavours from being uncompetitive and prone to foreign takeovers.
- *Securing mineral supply at the international level*. Countries such as the Czech Republic, Japan, Great Britain, and Germany implement policies at the international level to secure supply. They do so through establishing international
  strategic partnerships. These partnerships cover trade agreements, support in international forums, sharing of technology and development aid programmes. International partnerships are used strategically to secure mineral supply. A number of countries aim to create open markets and an international level

42 McEvoy, F. et al. (2008), Towards a Harmonised Policy Framework for Safeguarding Mineral Resources in Europe: A National case Study from England. http://www.cprm.gov.br/33 IGC/1136524.html. See also Gordon, R.L. (2008), 'Mineral Economics: Overview of a Discipline.' Resources Policy, Vol. 33, No. 1, pp. 4-11; Menzie, W.D. (1995), 'Public Attitudes and Policies Towards Mineral Resources on the Brink of the 21st Century.' Natural Resources Research, Vol. 4, No. 1, pp. 1-11.

playing field. By promoting free global markets the aforementioned countries try to secure both access to and the continuing flow of mineral resources, as well as openness in pricing and trading. Through international rules, regulations and regulatory institutions, they seek to safeguard the supply of minerals.

Visual representation of findings

The foregoing analysis provides insight into whether states consider mineral resources from a national security perspective. This section visualises these findings. The visual depiction rates national mineral policies on a scale from indirect use of power to using minerals as an instrument of power. In relation to previous depicted policy characteristics, indirect use of power includes national governance, global governance, technological development, and development cooperation. Direct use of power includes trade restrictions and pro-active acquisitions and the strategic use of minerals.

In evaluating the respective countries' mineral policies, the core issue is whether the policy has been designed to explicitly protect and further national security or strategic interests or whether the policy has other objectives. Analysing direct state involvement, public private partnerships, national coherent government policies, tariffs, and import restrictions, administrative barriers, anti dumping policies, direct subsidies, export subsidies, exchange rates, export restrictions, stockpiling, foreign direct investment, international strategic partnerships, development aid, and liberalisation of the world market, a comprehensive picture is depicted below.

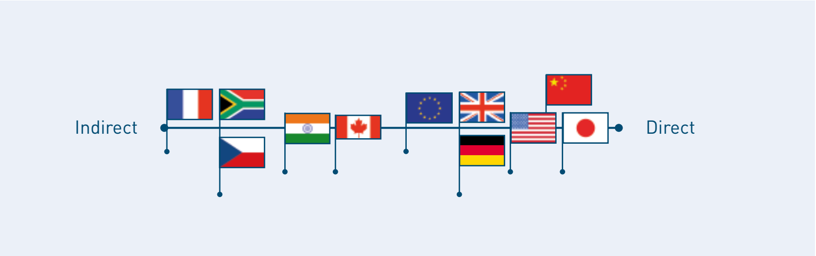


Figure 34. INDIRECT USE VERSUS DIRECT USE OF POWER

As figure 29 shows, mineral policies of the US, China and Japan explicitly protect and further national interests with a strategic objective in mind. Policies of the EU and Germany focus more on securing supply of scarce materials. Canada and India have similar mineral policy approaches; they lean towards moderately strategic policies given their focus on pro-active acquisition and national governance measures rather than on global governance and development cooperation. The remaining countries, France, Great Britain, South Africa and the Czech Republic, aim to gain access to minerals through primarily emphasising develop-ment cooperation in resource rich countries and global governance measures.

4.6 Recommended reading

Auty, R.M. (1993), *Sustaining Development in Mineral Economies: the Resource Curse Thesis*. London: Routledge.

Otto, J.M. (1997), 'A National Mineral Policy as a Regulatory Tool.' *Resources Policy*, No. 23, pp. 1-7.

5 Security implications

This chapter sketches the security implications of tightening mineral markets and the consequences for long-term supply. In policy debates, scarce minerals are increasingly framed as resources of high strategic value. As we have seen in the previous chapter, national policy documents, but also the EU's Raw Materials Initiative, indicate that governments are concerned about securing the long-term supply of scarce minerals. At the same time, countries that are rich in mineral resources devise strategies allowing them to capitalise on their natural resource endowments.

The strategic value of scarce minerals stems from three factors. First, a number of doping agents possess unique properties, which are currently indispensable to key high-tech applications.[43] For example, emerging technologies in the field of renewable energy and low-carbon dioxide emissions, some types of advanced weaponry (e.g. advanced missile systems or advanced armour plating), and advanced aerospace technologies. These doping agents are produced in very small quantities from a handful of mines around the world. Consequently, the countries that exploit these mines in principle control the access of other countries to such advanced technologies.

Second, even for minerals that are produced and used in larger quantities, n important share in world production potentially allows a country to exert influence on downstream industries through export restrictions and other trade barriers. If the processing of an element in a certain country is considerably cheaper than elsewhere due to protectionist measures, this may lead industries to relocate to such country in order to profit from preferential access to its raw materials. Finally, large mineral deposits can become an important source of

43 Angerer, Gerd (2009), Raw Materials For Emerging Technologies. Fraunhofer Institute for System and Innovation Research.

national income, especially in the case of developing countries whose economies are dominated by the primary sector.

These three factors explain why scarce minerals are increasingly considered as strategic goods and matters of national security. In an environment where the supply of mineral commodities is relatively abundant and suppliers compete for customers; the strategic value of scarce minerals is less. However, when supply considerations dominate markets and buyers compete for scarce resources, the strategic implications of minerals are more pronounced. It is therefore not surprising, that now that mineral markets have tightened considerably over the past years and experts are increasingly voicing concerns about the long-term sustainability of growth in output, scarce minerals have become a hot issue in the security domain.

Our analysis shows, that – as rapid demand growth shows little signs of abating notwithstanding a recent dip due to the world economic crisis – tight markets for key minerals are likely to remain vulnerable to tight supply for a considerable time to come. Conditions may worsen over the coming decades, if output cannot keep up with demand despite higher investments in the mining sector. Mineral markets are likely to remain tight over the coming years. Therefore, scarce minerals will remain a matter of strategic concern for the foreseeable future. The implications of the strategic use of mineral resources cannot be underestimated. In a world were minerals are not merely industrial inputs but also vital strategic assets, they are no longer produced where it is cheapest and sold to those who pay most. The geography of supply becomes pivotal and the supply of scarce minerals becomes subject to strategic and political considerations.

The impact of strategic considerations will affect the entire value chain. Minerals may be mined in countries where it is not economical to do so, in order to guarantee a minimal degree of self-sufficiency. Large companies backed by states may compete for concessions in the mining sector of resource rich countries, even if these investments are risky, not particularly profitable, or take place in countries with authoritarian regimes and a poor track record on human rights and environmental standards. Instead of being available to competitive bidding on global markets with equal access, scarce minerals may increasingly be traded through long-term supply contracts arranged between major corporations with heavy government involvement. Such deals may include preferential terms for political allies or political concessions, promises of development or military aid or technology transfers. Supplies may be denied to countries that are regarded as adversaries. In resource poor countries, consumption of certain minerals might be temporarily rationed or restricted. Governments may seek to focus R&D on substituting elements that are mined by hostile or unstable political regimes. Similarly they may seek to create or expand strategic reserves of certain elements as buffer against supply disruptions.

Consequently, the production, trade, and consumption of minerals are becoming increasingly politicised. This emerging political economy of scarce minerals is likely to have a negative effect on mineral scarcity as increased regulation and manipulation of trade in minerals will result in reduced efficiency of global markets, exacerbating scarcity. Furthermore, mineral markets may become increasingly sensitive to political shocks in producer countries and investments into mining industries are likely to suffer from growing political risk premiums. The mutually reinforcing effects of mineral scarcity and growing appreciation of scarce minerals as a strategic resource have the potential to create new or exacerbate existing conflicts. This may concern intrastate conflicts in countries that are rich in mineral resources. Especially in developing countries, the control of national mineral resources may become subject to intense rivalries within society that may fuel ethnic tensions or lead to civil wars.[44] According to UNEP, since 1990, 16 conflicts were caused by disputes over the control of natural resources.[45] Some examples are:

- Angola (1975-2002): oil and diamond
- DRC (1996-2008): copper, coltan, diamond, cobalt, wood, tin
- Ivory Coast (2002-2007): diamond, cacao, cotton
- Liberia (1989-2003): wood, diamond, iron, palm oil, cacao, coffee, rubber, gold
- Sierra Leone (1991 –2000), diamond, cacao, coffee
- Sudan (1983-2005): oil

Another consequence may be the creation of so-called rentier-states in which political, economic and social progress is hampered by elites that concentrate on capturing rents from natural resource exploitation rather than developing competitive economies and stable political institutions.

44 Collier, Paul & Anke Hoeffler (1998), 'On Economic Causes of Civil war.' Oxford Economic Papers, Vol. 50, No. 4, pp 563–573.

45 United Nations Environmental Program (2009), The Role of Natural Resources and the Environment.

Scarce mineral resources may also become subject to investment and trade disputes between resource rich and poor countries. Nations without mineral resources are likely to challenge trade restrictions and other protectionist measures of resource rich countries, or retaliate against such measures with punitive tariffs. Recent moves by the EU to challenge Chinese export restrictions on the basis of WTO rules are a good example of such effects.[46]

Similarly, large foreign direct investments in the mining sector of resource-rich economies may become subject to drawn-out investment disputes, between countries as well as between countries and multinational corporations. This risk is especially high in countries with poorly developed economic and legal institutions and unstable political regimes.

Finally, mineral scarcity may lead to competition between large powers that seek to increase control over mineral resources in third countries. Powerful countries may increasingly be prepared to work with questionable regimes or turn a blind eye to human rights violations or the suppression of political opposition, if governments open their mining sector to investments or supplies minerals on favorable terms. An example is China's investments into the primary sector of many African countries.

Scarcity of mineral resources: a European perspective

From a European point of view, increasing mineral scarcity is particularly worrisome, as few metallic mineral deposits worth exploiting are found on the continent. For a large number of metallic minerals, Europe is dependent on foreign supply. These include doping agents that are vital to products and production processes in the EU's extensive high-tech sector (see figure 35).[47]

Increasing mineral prices due to stuttering supply growth and rapid increases in global demand may have implications for long-term prosperity in Europe. However, the increasing access hurdles in global markets are even more worrisome. Major powers as the US, Japan, and China are taking measures to

46 'EU Requests WTO Consultations on Chinese Export Restrictions on Raw Materials', EUROPA Press Releases, 23 June, 2009. http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/09/287&format=HTML&aged=0&language=EN&guiLanguage=en

47 For a discussion of European dependence on imports of metallic minerals, see Commission of the European Communities (2008).

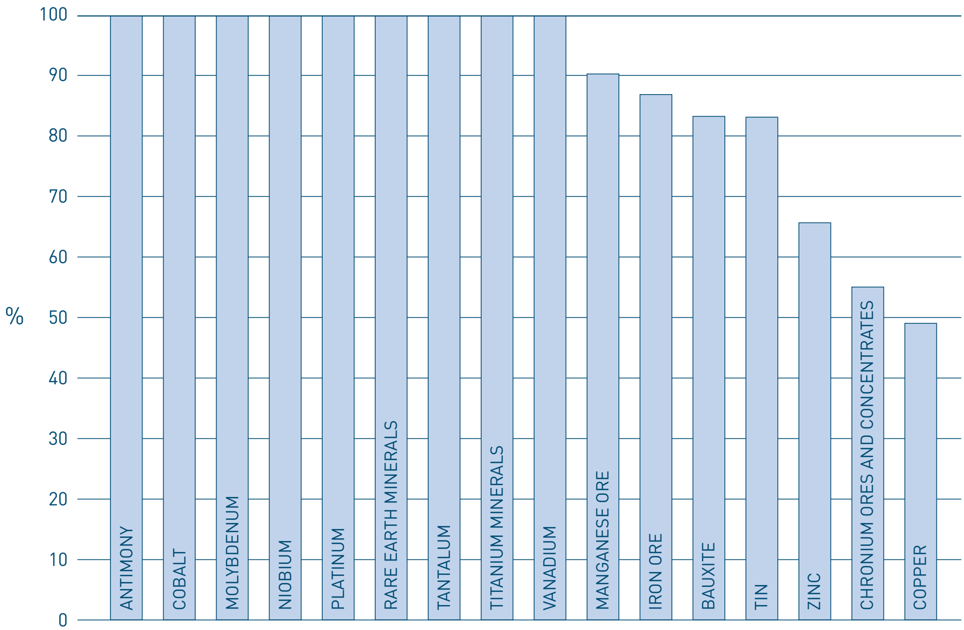


Figure 35. CONCENTRATES AND ORES, EU-27 NET IMPORTS AS A PERCENTAGE OF APPARENT CONSUMPTION.[48]

ensure preferential supply of minerals to their domestic industries.[49] Figure 35 gives an overview of strategic minerals for which China dominates world production; or many of these minerals China has proposed new, or reduced existing export quota. Such policies are detrimental to European interests because they increase global mineral scarcity and weaken the position of European industry vis-à-vis their competition.

48 Commission of the European Communities (2008), Commission Staff Working Document Accompanying 'The Raw Materials Initiative – Meeting Our Critical Needs for Growth and Jobs in Europe'. Communication from the Commission to the European Parliament and the Council, p. 4.

49 'World Faces Hi-Tech Crunch as China Eyes Ban on Rare Metal Exports.' Daily Telegraph, 24 August, 2009; 'China cuts 2010 Tin Export Quota by 9.87 Percent', ChinaMining.org, 2 November 2009. http://www.chinamining.org/Policies/2009-11-02/1257140683d30471.html

MINERAL	SHARE[50]	EXPORT QUOTA (2010)	MAIN APPLICATIONS
DYSPROSIUM	99%	Full export ban	Permanent magnet (electrical vehicles; windturbines)
LANTHANUM	95%	ca. 9.000 tonnes[51]	NiMH battery (electrical vehicles)
NEODYMIUM	95%	ca. 5.000 tonnes[52]	Permanent magnet (electrical vehicles; windturbines)
ANTIMONY	87%	57.500 tonnes	Semiconductors, solder
TUNGSTEN	84%	14.300 tonnes	High-performance steel; industrial cutting tools
GALLIUM	83%	-	Semiconductor (solar energy; LEDs; defense)
GERMANIUM	79%	-	Semiconductor (solar energy; fiber optics; infrared)
INDIUM	60%	233 tonnes	Semiconductor (LCD displays; solar energy; LEDs)
MAGNESIUM	48%[53]	1.330k. tonnes	Light-weight alloys (e.g. car bodies, airplanes)
TIN	40%	21.000 tonnes	Solder, tinplate (e.g. conservatives)
VANADIUM	38%	-	High-performance steel (e.g. jet engines)
MOLYBDENUM	28%	25.500 tonnes	High-performance steel (e.g. rocket engines)

Figure 36. STRATEGIC MINERALS FROM CHINA

50 Chinese share of world production, based on USGS Mineral Commodities Summaries 2009 and DG Enterprise and Industry calculations based on World Mining Data 2008.

51 Estimate as a share of the combined REE export quotum announced for 2010 (35.000 tonnes), based on abundance of La in the Earth's crust and common REE ores in Emsley, John (2001). Nature's Building Blocks, p220.

52 Idem for Nd.

53 According to the 2009 USGS Mineral Commodities Summaries report, China has an 87% share in the production of Magnesium metal and 41% in the production of Magnesium compounds.

While China is implementing stringent export restrictions for a number of minerals and thereby indirectly subsidises certain downstream industries, Japan and the US have created strategic stockpiles. There is a danger that individual countries increasingly seek bilateral agreements with Beijing that guarantee access to key minerals. Such policies threaten to limit European access to a number of key emerging technologies. They also diametrically contradict free-trade agreements and WTO rules that establish free and equal access to global markets.[54]

The direct consequences of such protectionist policies have been felt particularly hard in markets for doping agents, where supply is highly concentrated and trading volumes are small. How vulnerable these resources are to distorting policies is demonstrated by the fact that the introduction of new restrictions has lead to very large price jumps.

Policy implications for the EU

Europe's policy response to this emerging challenge has been rather slow and hesitant. While several member states have developed an explicit policy on minerals (including Germany, the UK and to a lesser degree France), many smaller member states have not developed a policy on scarce minerals, or, as in the case of the Netherlands, are in the process of doing so. Existing mineral policies differ considerably. The EU Raw Materials Initiative is a laudable first step in coordinating policy approaches. However, a common European policy on scarce minerals, which pro-actively ensures the protection of a level global playing field for European companies that depend on such minerals, is still lacking. Such a common approach requires a common rejection of protectionist policies of certain resource-rich developing countries, such as China. It also requires a clear message to allies like the US and Japan that go-it-alone policies, which improve the supply situation of individual powers at the expense of the global community, are unacceptable from a European perspective.

Even if the EU is poorly endowed with minerals, if it acts united, the EU has – due to the size and economic weight – significant leverage in global affairs to challenge its decreased competitiveness in global mineral markets. A firm European position on mineral related issues could be actively promoted in

54 World Trade Organisation (2001), Protocol on the Accession of the People's Republic of China.

multilateral fora like the WTO, World Bank, or the G-20. Simultaneously, Europeans should demand that allies in the G-8, NATO, World Economic Forum, OECD and similar institutions join the EU in actively protecting and promoting free market principles in mineral markets. When mineral policies of other powers violate free trade rules, legal measures should be pursued to the fullest extent and where necessary, retaliatory trade measures should be considered.

Rising mineral prices and the risk of mineral scarcity pose serious challenges to Europe and the world. Europe can't afford scarce minerals to become prey to protectionist policies. Such developments would seriously hamper European access to key emergent technologies and threaten the competitiveness of European industries.

Conclusions

Growing demand and rising prices for minerals worldwide beg the question whether minerals will soon be in short supply. The analysis in this report shows that predictions of certain elements being 'mined to extinction', are not realistic. Demand, supply, recycling, and exploration dynamically adjusts to changing prices and over time act to mitigate scarcity to some degree. Nonetheless, scarcity of minerals may occur and create tight, volatile markets that are sensitive to supply interruptions and speculative hikes.

Continued industrialisation of the developing world will lead to rising global demand for minerals. Emerging economies will consume a growing share of global mineral output and increasingly compete with Western countries over access to scarce mineral reserves. Emerging economies are also starting to contribute significantly to the output and consumption of high-tech products. From 1950-2000, global output of the sample of 15 elements and two element groups we examined on average increased fivefold. From 2000-2007, however, production of precious metals in this sample grew by 17%, mass consumables by 33%, and doping agents by 46%.

Prices are indicative of scarcity for consumers and producers. While prices have fallen for over two decades after spiking sharply in the 1980's, this trend has reversed over the past couple of years. Real prices have more than doubled since 2002 and have reached a level not seen since the Second Oil Shock nearly three decades ago. Our analysis demonstrates that mineral scarcity will most likely be an issue in the coming decades, although it is uncertain when and to what extent.

Demand will keep increasing and mineral suppliers will struggle to expand global mineral output at the same rate as over the past hundred years. The expansion of global mineral output over the past one and a half centuries has led to a geographic shift in mineral production. The global distribution of mineral reserves i.e. – deposits are economically exploitable with current technologies –

is highly asymmetric. For most elements, global reserves are located in a handful of countries. Currently, six resource rich developing countries provided a quarter of world production. The trend of production away from Western countries, with the important exceptions of Canada and Australia, towards developing countries is continuing into the new millennium and has major geopolitical implications. This shift reflects two trends. First, the rapid industrialisation of many parts of the world outside of the US and Western Europe over the 20th century has made industrial mining a global phenomenon. Second, the widespread depletion of economically competitive reserves in those countries that industrialised early on has pushed exploration and mining away from Western Europe and the US towards areas that were previously untouched.

There are serious concerns as to whether mineral production can keep up with rising demand, given the increasing *geological* and *geographical distance* to minerals. Past mining has picked the 'low-hanging fruit' and depleted those resources that were of the highest quality, easiest to extract and closest to consumers.

Future mining operations face an increasing geological distance, meaning mining deposits of lower ore grade, which are found in deeper and less accessible layers in the planet's crust. Deposits are also located at greater geographic distance from centres of consumption and in less accessible environments (e.g. offshore). These trends are likely to make mining more energy intensive. Given the volatility of energy prices, this might lead to much higher and less predictable production and processing costs.Countries respond differently to the challenge of mineral scarcity. Mineral reserves and consumption are unevenly distributed around the globe and scarcity is likely to affect different countries in different ways. Our analysis of official mineral policies shows that some countries consider mineral supply primarily a technological issue. Technological innovation is seen as key to securing mineral supply. Driven by increasing concerns over securing supply of raw materials and growing awareness of the need to manage finite resources in responsible manner, policy makers are also beginning to appreciate the importance of safeguarding access to mineral resources. Other countries view minerals as a security issue. They typically focus on the identification and stockpiling of critical minerals. For this, minerals are designated as critical for national security and policies are designed to secure supply of these critical minerals. Often, state resources are used to gain access or acquire these critical minerals. However, a global scramble for minerals and energy may add to the instability of a changing world.

This study identifies a number of policy measures at the national and international level that are employed by different states to improve security in the supply of minerals:

- *Securing mineral supply at the national level*. Direct state involvement is used by a number of countries (amongst others the US, China, and Japan) to strengthen governmental grip on the supply of minerals.
- *Increasing domestic capacity*, particularly mapping, extracting and refining minerals is an important aspect of securing mineral supply at the national level, especially for resource rich countries.
- *Securing mineral supply at the international level*. Several countries actively pursue policies at the international level to improve access mineral supplies. They do so through establishing strategic partnerships with important producer countries. Further, several countries aim to create open markets and a level international playing field through international rules, regulations and regulatory institutions.

Instead of being available to competitive bidding on global markets with equal access, scarce minerals might increasingly be traded through long-term supply contracts arranged between major corporations with heavy government involvement. Such deals might include preferential terms for political allies or include political concessions, promises of development or military aid or technology transfers.

Supplies might be denied to countries that are regarded as adversaries. In resource poor countries, consumption of certain minerals might be temporarily rationed or otherwise restricted. Governments in these countries might seek to focus R&D on substituting elements that are mainly mined by hostile or unstable political regimes. Similarly they might seek to create or expand strategic reserves of certain elements as buffer against supply disruptions.

Given concerns about access to critical mineral resources, they might increasingly be mined in countries where it is not economical to do so, in order to guarantee a minimal degree of self-sufficiency. Large companies backed by state powers are likely to compete to gain concessions for foreign direct investment in the mining sector of resource rich countries, even if these investments are risky, not particularly profitable, or take place in countries with authoritarian regimes and a poor track record on human rights and environmental standards.

What are the implications of these developments for Europe? For a number of metallic minerals, Europe is overwhelmingly dependent on foreign supplies to satisfy its industrial demand. This includes doping agents vital to products and production processes in the continent's extensive high-tech sector. China dominates world production of many of these strategic minerals for which it has recently proposed new, or reduced existing export quotas. Such policies are detrimental to European interests because they increase global mineral scarcity and weaken the competitive position of European industries.

How successful Europe and the rest of the world will be in responding to the challenge of mineral scarcity depends on four key factors:

1. Energy scarcity. Energy is required to mine, refine and process minerals. As geological and geographical distance increase, mining and refining minerals is bound to become more energy intensive. Increasing energy scarcity – e.g. due to the rapid exhaustion of fossil fuels and a slow expansion of renewable energy sources – will exacerbate mineral scarcity. Crude oil prices are a suitable approximation of global energy prices, which in turn impact on mineral prices. Our analysis shows that the development of mineral prices is remarkably in sync with the evolution of the crude oil prices. The relationship between energy and mineral prices is an issue with potentially important ramifications for the scarcity debate.
2. Success in substituting scarce elements, particularly in key high-tech applications and emergent technologies. Mineral scarcity is a phenomenon that affects different elements in different ways. If industries are able to substitute scarce elements with more abundant ones, this will mitigate the worst effects of scarcity. If substitution is difficult, as it is currently the case for some scarce elements used in emergent and 'green technologies', mineral scarcity will have a more disruptive impact.
3. Reduction of scarce minerals consumption per capita in affluent societies, and recycling of scarce mineral resources globally.
4. The balance between increasing geological and geographical distance, and R&D in mining technology which enables mining companies to profitably dig for lower quality ores, at greater depths, in more remote locations.

Scarcity of minerals is thus an issue that deserves urgent attention from policymakers. It is also a complex phenomenon and subject to high degrees of uncertainty. Rather than short-term action based on fears of depleting known mineral reserves, prudent, long-term approaches are needed to mitigate mineral scarcity and prevent its most disruptive effects.

Compared to debates on water and energy scarcity, the debate on mineral scarcity is just beginning. Our analysis indicates that there are critical questions that need to be addressed in-depth to gain a better understanding of mineral scarcity, such as:

- Does the current growth of real mineral prices present a permanent shift or a temporary price hike?
- How will developments in the energy domain affect mineral scarcity?
- What policies with regards to scarce minerals could be considered as most successful 'best-practice' approaches?
- Can early-warning systems be developed to monitor the risk of supply disruptions?
- What are the short, medium and long-term effects of the mineral scarcity on the European and Dutch economies? Which minerals are used to what extent in European and Dutch industries?
- Can we model or cascade effects from mineral scarcity to the scarcity of water, energy, and food?
- Which vital industries or infrastructures are influenced by mineral scarcity?
- Is there a critical window of opportunity for mitigating mineral scarcity risks and are timely solutions available?
- Reduce, re-use and recycle mechanisms can play an important role in phases of transition. How can these mechanisms be made economically viable?
- Is there a tendency to nationalize mineral resource industries and if so why?
- Can trade politics solve the problem?
- Which state and non-state actors in the mineral environment could form a threat for mineral supplies Europe and the Netherlands?
- What policy instruments are available for governments to mitigate minerals scarcity effectively?

Annex A: Description of elements

HCSS compiled data on a sample of fifteen elements and two groups of elements (rare earth and platinum metals). A database of annual production, reserves, recycling and price series was assembled from a wide range of sources, in some cases covering a period of more than a 100 years. The database contains data on world market prices, output quantities, on geography and distribution, United States primary and secondary production. The most important publicly available dataset came from the United States Geological Survey. This institute has the most extensive data available over the longest period. It was checked and normalised and completed with data from the British Geological Survey. The database also contains information on the geographic location of production and reserves and its evolution over time. Production and reserve data were plotted on maps and in graphs to show the location of current reserves and the trends in production. Unfortunately, no time-series on the share of secondary production in global mineral output are available at present. Therefore, the database contains US secondary production data for some elements over several decades. This section presents a historical time series on the total share of secondary production in US mineral output from 1900 to 2008. The analysis is based on aggregated production rates of new scrap, refined scrap, secondary production and secondary production toll-refined in combination with primary production rates. When data are not available this is stated in the text.

A.1 Mass consumables

Copper

Characteristics and use

Copper is a non-ferrous base and transition metal, thereby enabling it to form compounds such as chalcopyrite and copper ions in solution. It occurs naturally in all plants and animals as it is an essential element for all known living organisms. Copper contributes with a number of elements and as such, more than 150 copper minerals have been identified. These copper minerals can be divided into three groups: 1) primary and hypogene minerals, 2) copper oxides, and 3) secondary sulphides; chalcopyrite, part of the primary and hypogene minerals, is the main copper ore.

Its ability to conduct electricity and heat are two of copper's most important properties; about a quarter of all copper that is produced is also used in electrical applications. Its resistance to corrosion has furthermore to use of copper in architecture where under primarily roofing. Alloyed with other metals it can acquire additional preferred properties such as increased hardness; brass and bronze are two of the most important alloys with this property.

Global reserves

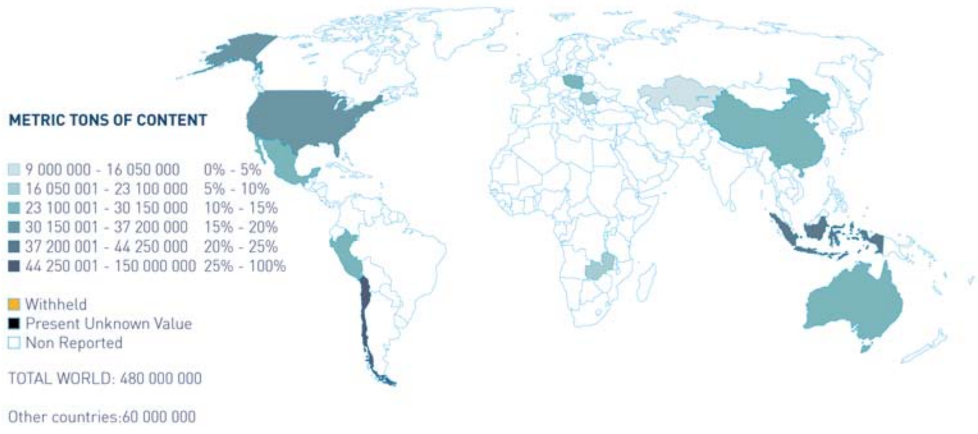


Figure 37. GLOBAL COPPER RESERVES

Production

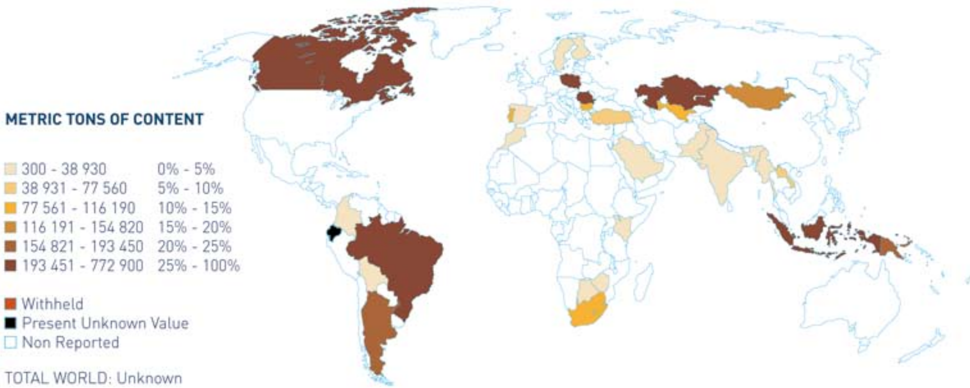


Figure 38. GLOBAL COPPER PRODUCTION

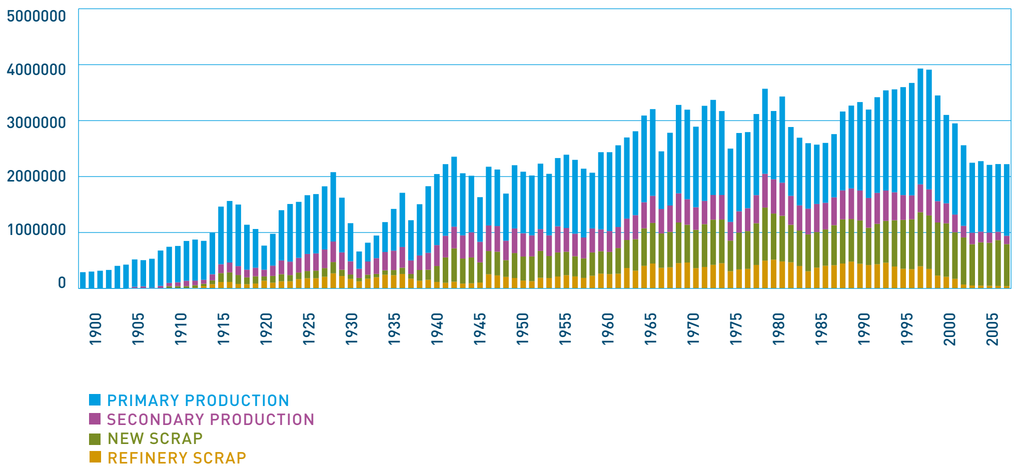


Figure 39. COPPER US SECONDARY PRODUCTION PROPORTIONATE TO PRIMARY PRODUCTION

Available US data shows that recycling of copper has taken place since the beginning of the 20th century. As proportion of primary production, copper has experienced a relative stable growth of secondary production, refinery scrap and new scrap until the turn of the millennium. Production has remained proportionate to primary production throughout the period. Around 2000 there is a noticeable decrease in primary production with secondary production and refinery scrap following suite. New scrap production remains relative stable. Lower copper prices in 2000 and closure of one secondary copper smelter are possible explanations to the ongoing downward trend. Furthermore, as strong export markets have served to bolster (old) scrap prices and environmental regulations have tightened, (old) scrap production has been left with narrower processing margins; and as operating costs are high and large additional capital investment is needed to comply with environmental regulations, domestic (old) scrap production is said to have become discouraged. An example of what this development has led to is the cost squeeze that has arisen, causing the closing of all U.S. secondary smelters and associated electrolytic refineries. Of the four secondary smelting and two electrolytic refining firms operating in 1996, none remained after 2001.[55] These same developments may then explain the relative stable and slightly increasing recycling of new scrap as this is scrap from the primary production line and therefore perhaps more easily accessible and manageable.

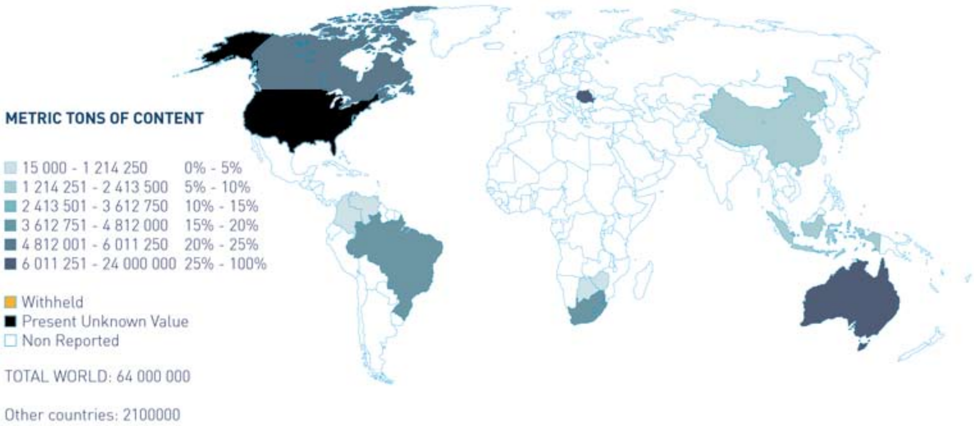
Nickel

Characteristics and use

Nickel is a chemical element and a transition metal. Its most important ore minerals are laterites including limonite and garnierite, and pentlandite. Main exploitable deposits are found in Canada and Russia. As nickel is corrosion resistant, it is used in an array of industrial and consumer products and processes such as plating, in magnets and coinage, in rechargeable batteries and several household utensils. Pre-eminently however, nickel is valuable for the alloys it forms, especially super alloys in the form i.e. stainless steel. Nickel compounds include nickel-sulphate used for electroplating nickel and nickel-oxide used as cathode or electrode in several types of rechargeable batteries including nickel-cadmium, nickel-iron and nickel-hydrogen batteries.

55 Copper Development Association (2009), The U.S. Copper-base Scrap Industry and Its By-products – 2008. http://www.copper.org/publications/pub_list/pdf/scrap_report.pdf

Global reserves



Production

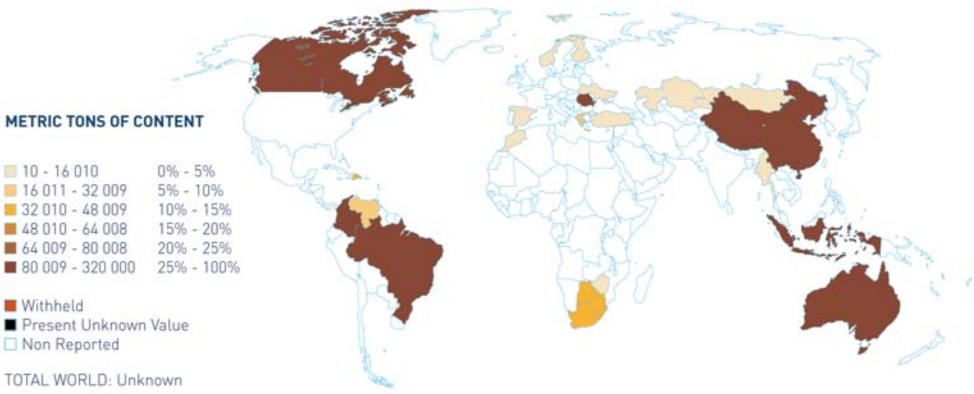


Figure 41. GLOBAL NICKEL PRODUCTION

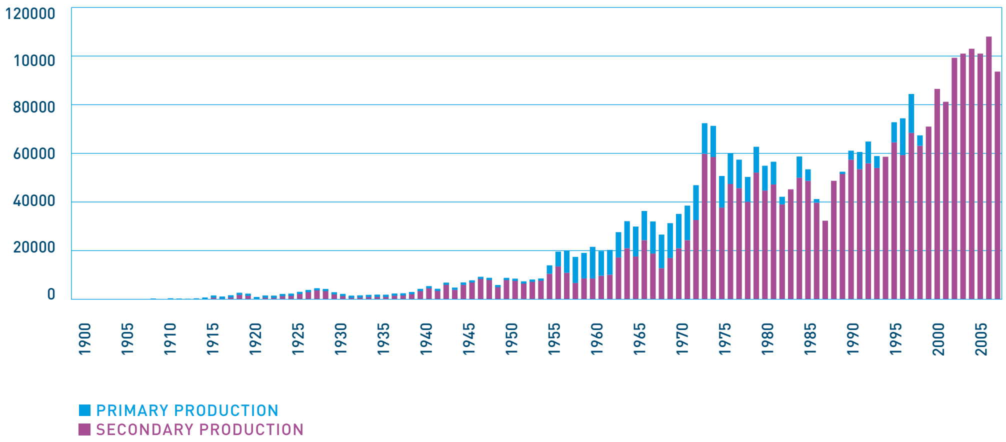


Figure 42. NICKEL SECONDARY PRODUCTION AS SHARE OF PRIMARY PRODUCTION

Since 1940 we see a stable increase in secondary production rates with little primary production until the mid 1990´s and no primary production after the 1990's. The United States does not have any active nickel mines. The only nickel smelter in the United States – a ferronickel operation near Riddle, closed in April 1998 because of low nickel prices. The adjoining mine on Nickel Mountain has been idle since 1996. What is seen in the graph is primarily recycling of recovered material from purchased (steel) scrap. Nickel however has been a strategic and critical material in every major conflict fought by the United States since 1900, with the U.S. Government having to allocate or ration the metal in almost every instance. This both explains the peaks in secondary production as well as the secondary production over all. World War I caused world production of nickel steel to soar and the development of stainless steel between 1905 and 1912 further accelerated demand for nickel as nickel is an essential part of stainless steel.
The discovery of nickel-base super-alloys during the 1930s permitted the development of jet aircraft engines and rocket engines during World War II.
In the 1980s, soaring sales of mobile telephones, the invention of the laptop computer, and a resurgence of interest in electric vehicles led to the development of the nickel metal hydride battery. In 2000, Russia, Canada, and Australia were the largest nickel mining countries and are also the countries from which the US imports most of it nickel and nickel containing scrap.

Tin

Characteristics and use

Tin is one of the earliest metals known and used. Having a hardening effect on copper, tin was used in bronze implements as early as 3,500 B.C. As a pure metal it was not used until about 600 B.C. About 35 countries mine tin throughout the world. Nearly every continent has an important tin-mining country. Most of the world's tin is produced from placer deposits - at least one-half comes from Southeast Asia. The only mineral of commercial importance as a source of tin is cassiterite but small quantities of tin are also recovered from stanite, cylindrite, frankeite, canfieldite, and teallite. Most commonly tin is used as a protective coating or as an alloy with other metals such as lead or zinc. Tin is used in coatings for steel containers, in solders for joining pipes or electrical/electronic circuits, in bearing alloys, in glass-making, and in a wide range of tin chemical applications. Secondary, or scrap, tin is an important source of the tin supply.

Global reserves

Figure 43. GLOBAL TIN RESERVES

Production

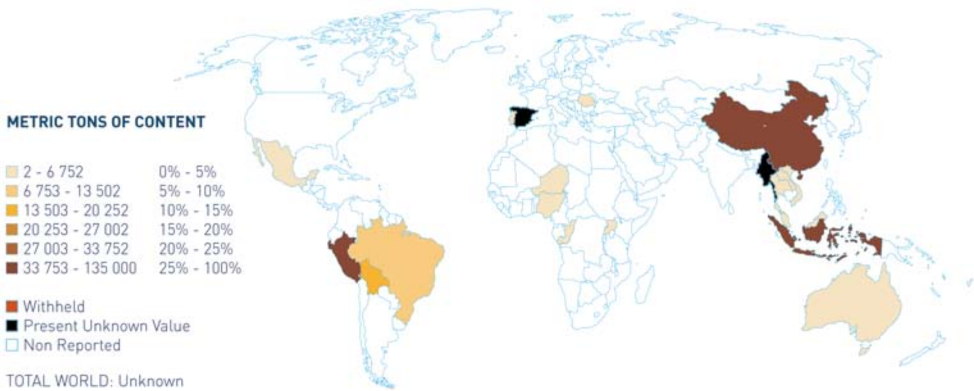


Figure 44. GLOBAL TIN PRODUCTION

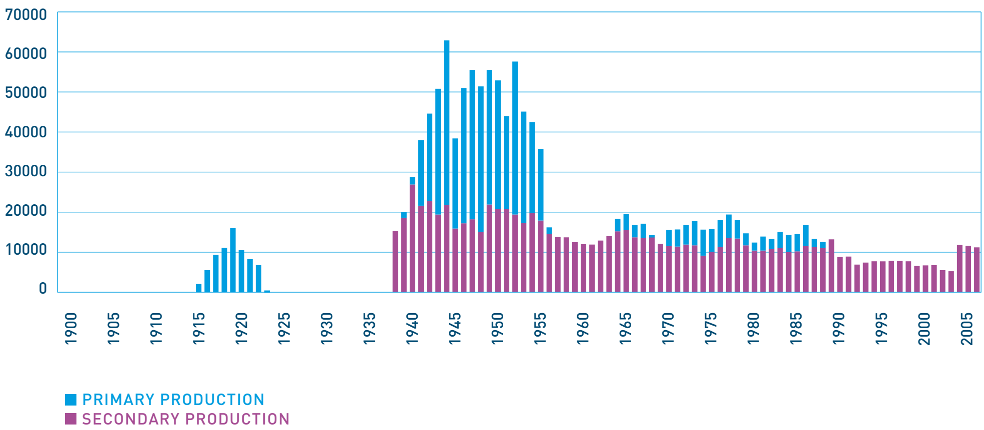


Figure 45. TOTAL US TIN SECONDARY PRODUCTION AS SHARE OF PRIMARY PRODUCTION

Secondary production takes off at the end of the Second World War and is, with a slight advantage for primary production, proportionate to primary production between 1940 and 1960. From the 1960's, not only primary production decreases noticeably, but also a slowly decreasing secondary production is noticeable until 2005 where an increase in secondary production occurs. Since end of 1980's, available data shows no primary production.

In 1900 the US was the world's major tin user, a status the country has maintained until today. In the 1900's, the US depended almost entirely on tin imports to accommodate its needs and with no domestic tin mine or smelter production today, this still holds true. Solder, tinplate and tinning have been and are the major uses for tin. In 1900 all tinplate was made by hot-dip process. The development of the electrolytic tinplate process in the late 1930's (under the impetus of an accelerating war effort production) probably explains increasing (secondary) production rates. Furthermore, in 1939, tin became the first material purchased by the US Government for its stockpile programme.

Zinc

Characteristics and use

Zinc is a chemical element and a transition metal. The most exploited zinc ore is sphalerite, a zinc sulphide, but zinc is also extracted from minerals such as smithsonite (zinc carbonite) and hemimorphite (zinc silicate). About 70% of the world's zinc originates from mining, while the remaining 30% comes from the recycling of secondary zinc. As zinc can not be extracted directly, zinc production includes froth flotation of the ore, roasting and final extraction through electro-extraction. Main exploitable deposits are found in Australia, Canada and the United States.

Zinc is most commonly used as an anti-corrosion agent through the process of galvanization. The relative reactivity of zinc and its ability to attract oxidation to itself also makes it a good sacrificial anode in cathodic protection: the dissolving of the zinc protects other metallic components from corroding. As such it can used to protect steel, water and fuel pipelines, ships, off shore oil platforms etcetera. Binary compounds for zinc are known for most metalloids and all non-metals except the noble gases. Among zinc compounds, zinc oxide is widely used, primarily as an additive to plastics, ceramics, cement, rubber, batteries and in foods as source of zinc nutrient.

Global reserves

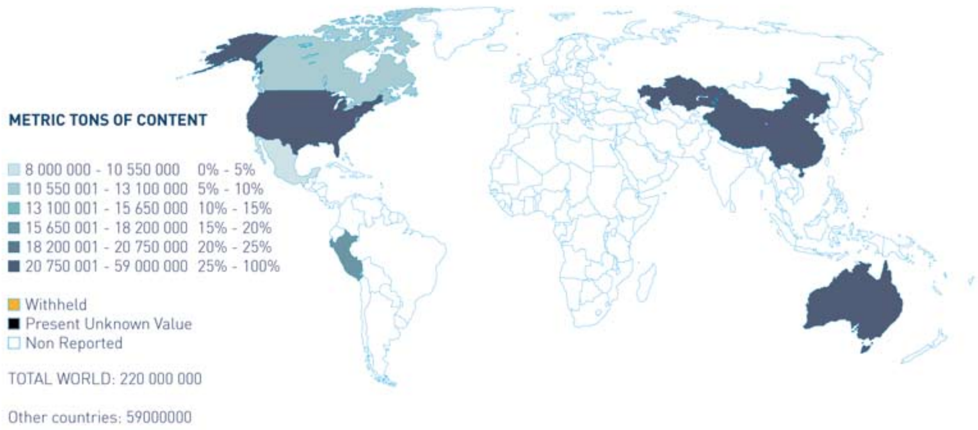


Figure 46. GLOBAL ZINC RESERVES

Production

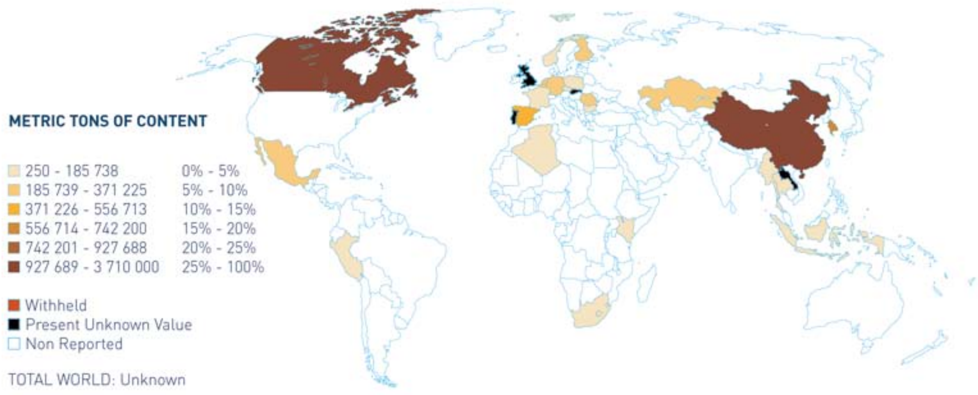


Figure 47. TOTAL GLOBAL ZINC PRODUCTION

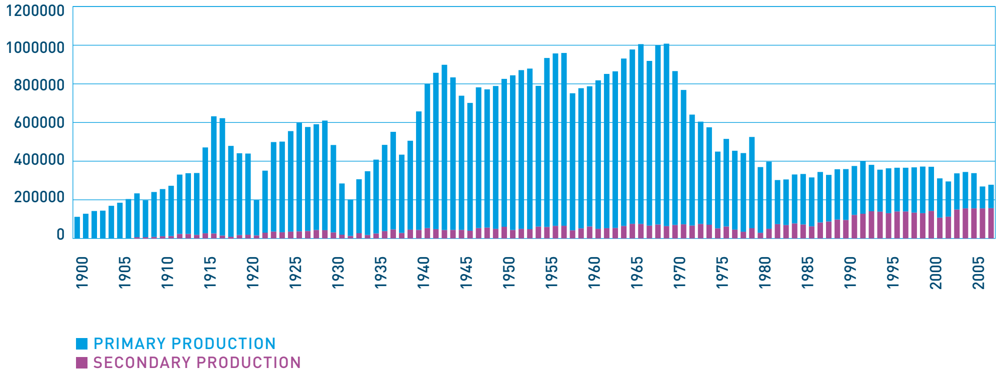


Figure 48. ZINC US SECONDARY PRODUCTION AS SHARE OF PRIMARY PRODUCTION

In regards to zinc secondary production we can see a rather stable but slow increase. Today secondary production is proportionate to primary production with steadily decreasing primary production.

In the beginning of the 20th century the US was the world's leading producer of zinc, a position held until the beginning of the 1970's. Beneficiation processes over the century explain the displayed increase of primary production, as have advancements in retort smelting and the introduction of electrolytic processing. Increasingly stringent environmental laws from the 1970's have been suggested as reasons for decreasing amounts of primary production (and subsequent increasing amounts of secondary production), further resulting in the US today only having three active primary smelters.

In regards to secondary production approximately 30% of the zinc produced originates from recycled or secondary production of steel. However, zinc containing products are comparably slow to enter the recycling circuit due to the metal's durability. The life span of zinc containing products ranges from 10-15 years for cars and household appliances to over 100 years for zinc sheets used in roofing.[56] The relative low grade of recycling may partly be explained by this.

56 International Zinc Association (2009), Zinc Recycling. http://www.zinc.org/recycling.html.

A.2 Doping Agents

Gallium

Characteristics and use

Gallium is a chemical element which does not occur in nature as a free element, but as Ga (III) salt, in trace amounts in bauxite and zinc ores. Being a soft silvery metallic poor metal, elemental gallium is also brittle solid at low temperatures. As it liquefies slightly above room temperature, it will melt in the hand. Its melting point is used as a temperature reference point, and from its discovery in 1875 to the semiconductor era, its primary uses have been in high-temperature thermometric applications and in preparation of metal alloys with unusual properties of stability, or ease of melting. In semiconductors, an important application of gallium today is in the compounds gallium arsenide and gallium nitride, used most notably in LEDs. Semiconductor use is now almost the entire (> 95%) world market for gallium.

Global reserves

No time series for global reserves available.

Production

No time series for global production available.

Lithium

Characteristics and use

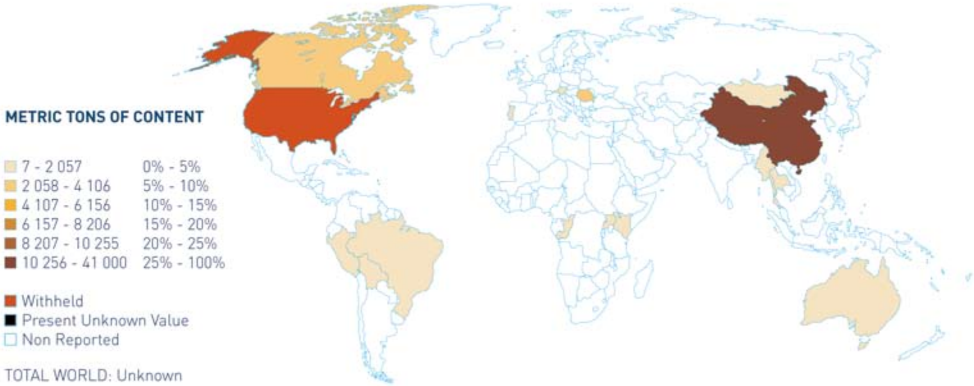
Lithium is a chemical element and an alkali metal. It is the lightest metal and the least dense solid element. Being an alkali metal, it is highly reactive, quickly corroding in air. Due to its high reactivity it only appears naturally in compounds in pegmatitic minerals, brines and clays and only in small quantities.

Lithium and its compounds primarily serve industrial applications including heat resistant glass and ceramics, in heat transfer applications and in the fine-chemical industry. In nuclear physics, lithium is used as fusion fuel. Deposits of lithium are primarily found in South America throughout the Andes mountain chain. From brine pools, lithium is also extracted in the US.

Global reserves

Figure 49. GLOBAL LITHIUM RESERVES

Production



Molybdenum

Characteristics and use

Molybdenum is a chemical element and a transition metal. It does not occur as a free metal in nature but as a variety of oxidation states in minerals such as wulfenite, powellite and molybdenite. Main deposits are found in the US, Canada, Chile, Russia and China.

Molybdenum can withstand extreme temperatures without significantly expanding or softening and is therefore useful in the production of applications that involve intense heat such as aircraft parts, industrial motors and filaments. Molybdenum compounds are furthermore used in high strength steel alloys, as pigments and as catalysts. The compound molybdenum-disulfide is used as a solid lubricant and an extreme pressure anti wear agent as it forms films on metallic surfaces (whereby preventing metal-on-metal contact).

Global reserves

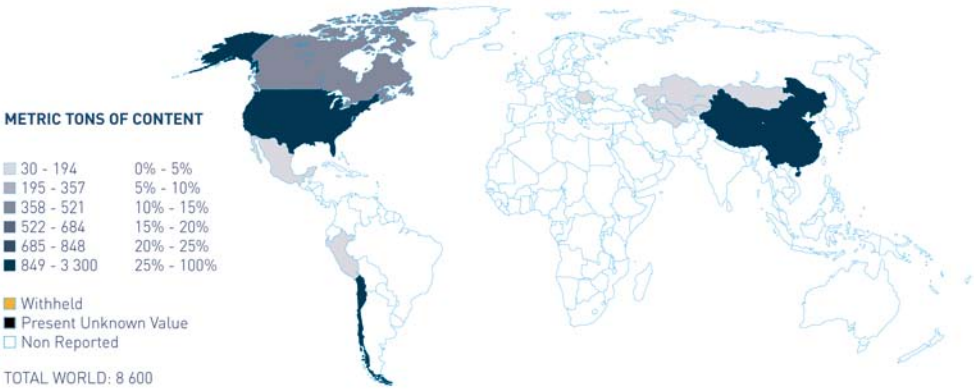


Figure 51. GLOBAL MOLYBDENUM RESERVES

Production

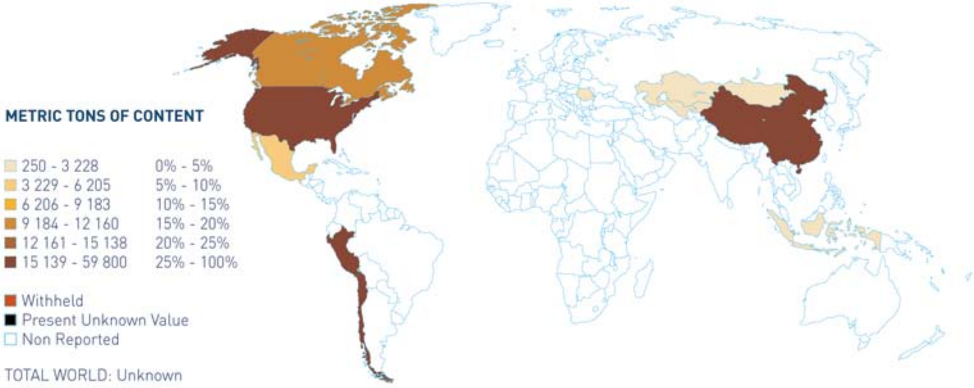


Figure 52. GLOBAL MOLYBDENUM PRODUCTION

Niobium

Characteristics and use

Niobium, a ductile transition metal, was previously known as columbium; columbium was the name given in 1801, and niobium was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. In the form of ferroniobium, niobium is used worldwide, mostly as an alloying element in steels and in superalloys. Appreciable amounts of niobium in the form of high-purity ferroniobium (an alloy of iron and niobium) and nickel niobium are used in nickel-, cobalt-, and ron-base superalloys for such applications as jet engine components, rocket subassemblies, and heat-resisting and combustion equipment. The physical and chemical properties of niobium are similar to those of the chemical element tantalum. The two are therefore rather difficult to distinguish. Brazil and Canada are the major producers of niobium mineral concentrates.

Global reserves

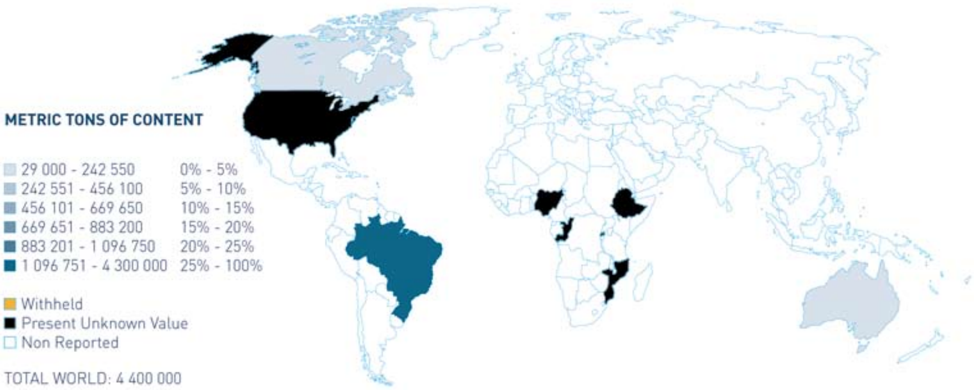


Figure 53. GLOBAL NIOBIUM RESERVES

Production

Figure 54. GLOBAL NIOBIUM PRODUCTION

Hafnium

Characteristics and use

Hafnium is a chemical element and a transition metal found in zirconium minerals. Hafnium is used in filaments, electrodes and semiconductor fabrication processes for integrated circuits. Through its ability to absorb neutrons, it is also used in control rods in nuclear power plants. In i.e. titanium, niobium and tantalum alloys, it can also be used in liquid rockets. Main extraction areas include Australia, Brazil and Malawi. Hafnium forms various kinds of inorganic compounds. Together with halogens it reacts to form hafnium tetrahalides and at higher temperatures it reacts with oxygen, nitrogen, carbon, boron, sulphur and silicon. Hafnium compounds can furthermore be subjected to very high temperatures; together with tantalum it, for example, possesses the highest melting point of any currently known compound, 4215 C.

The technical uses for hafnium are not many, mainly due to the close similarity between hafnium and zirconium (which makes it possible to use the cheaper zirconium for most of the applications). Furthermore, the relatively small amounts available and the difficult separation techniques necessary make hafnium a scarce metal.

Global reserves

Figure 55. GLOBAL HAFNIUM RESERVES

Production

No time series for global production available.

Tantalum

Characteristics and use

Tantalum, a lustrous and ductile transition metal, is easily fabricated, highly resistant to corrosion by acids and a good conductor of heat and electricity and has a high melting point. The major use for tantalum, as tantalum metal powder, is in the production of electronic components and there mainly tantalum capacitors. Major end uses for tantalum capacitors include portable telephones, pagers, personal computers, and automotive electronics. Alloyed with other metals, tantalum is also used in making carbide tools for metalworking equipment and in the production of superalloys for jet engine components. Australia, Brazil, and Canada are the major producers of tantalum mineral concentrates.

Global Reserves

FIGURE 56. GLOBAL TANTALUM RESERVES

Production

Figure 57. GLOBAL TANTALUM PRODUCTION

Tungsten

Characteristics and use

Tungsten, also known as wolfram, is in its raw form often brittle and hard to work. If pure, it can however be worked fairly easily. Tungsten is found in several mineral ores, including wolframite and scheelite. It is a metal with a wide range of uses, the largest of which is as tungsten carbide in cemented carbides.

Cemented carbides (also called hard metals) are wear-resistant materials used by the metalworking, mining, and construction industries. Tungsten metal wires, electrodes, and/or contacts are used in lighting, electronic, electrical, heating, and welding applications. Tungsten is also used to make heavy metal alloys for armaments, heat sinks, and high-density applications, such as weights and counterweights; super alloys for turbine blades; tool steels; and wear-resistant alloy parts and coatings. Tungsten composites are used as a substitute for lead in bullets and shot. Tungsten chemical compounds are used in catalysts, inorganic pigments, and high-temperature lubricants.

Global reserves

Figure 58. GLOBAL TUNGSTEN RESERVES

Production

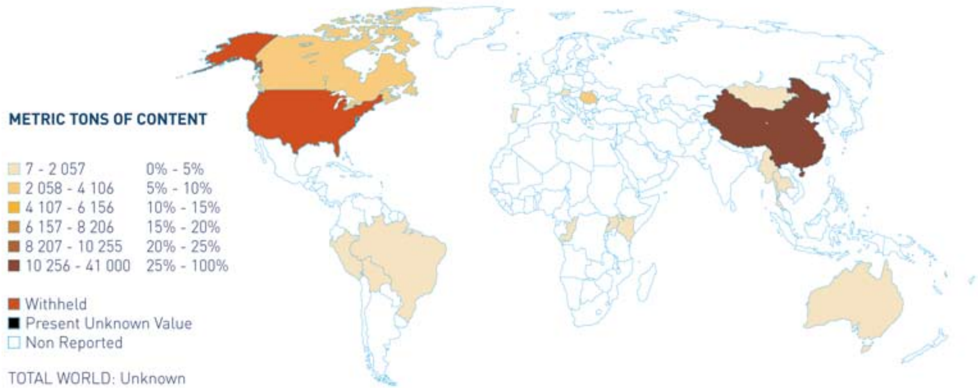


Figure 59. GLOBAL TUNGSTEN PRODUCTION

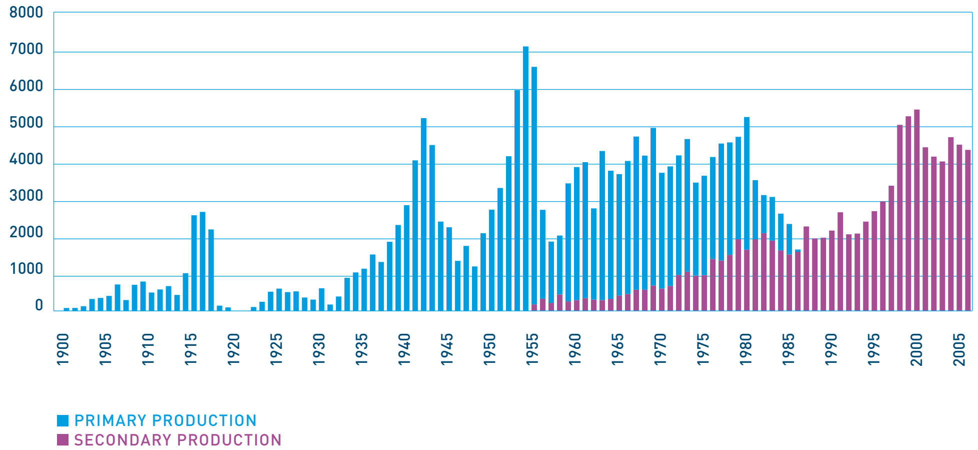


Figure 60. TOTAL US TUNGSTEN SECONDARY PRODUCTION AS SHARE OF PRIMARY PRODUCTION

Secondary production of tungsten took of in the mid 1950's and has since steadily increased. The most striking feature of tungsten production development as shown in the graph is the dip in primary production as of the 1980's with a complete stop of primary production in 1985. It took the secondary production market about 20 years to adjust the primary production levels from 1980's.

US primary production of tungsten has always been limited in comparison to the amounts of tungsten consumed. As such, the US has long been dependent on imports of tungsten. In 2008, no tungsten was mined in the US. Secondary production of the metal is therefore secondary production of end-life products and imported scrap. The sharp decline in tungsten primary production around 1980 can be explained by the sharp recession that hit the market at the same time.

In general, the fluctuations of tungsten primary production can be explained by market prices adjusting between periods of scarcity and oversupply. In addition to general economic conditions and industrial activity, China's position as the world's largest producer; changes in availability from Communist or formerly

Communist countries; purchases for or sales from various Government stockpiles; trade controls; build-up of or reduction in inventories held by industry; fluctuations in production by a large number of widely dispersed small producers; differing political, social, and economic objectives of producing countries; industry fragmentation in that most countries that produce tungsten are not large consumers; rapid shifts in demand; and increases in demand in support of military activity, have all been factors suggested as having affected the tungsten market over time.[57]. The heavy fluctuations in price of primary tungsten also explain the rather constant increase in secondary production.

Zirconium

Characteristics and use

Zirconium is a transition metal with its principal economic source being the zirconium silicate mineral, zircon. Zircon is also the primary source of all hafnium. Zircon is a coproduct or byproduct of the mining and processing of heavy-mineral sands for the titanium minerals, ilmenite and rutile, or tin minerals. The major end uses of zircon are refractories, foundry sands (including investment casting), and ceramic opacification. Zircon is also marketed as a natural gemstone, and its oxide is processed to produce the diamond simulant, cubic zirconia. Zirconium is used in nuclear fuel cladding, chemical piping in corrosive environments, heat exchangers, and various specialty alloys. The major end uses of hafnium are in nuclear control rods, nickel-based superalloys, nozzles for plasma arc metal cutting, and high-temperature ceramics.

57 Shedd, K. (1998), Annual Average Tungsten Price. United States Geological Survey.

Global reserves

Figure 61. GLOBAL ZIRCONIUM RESERVES

Production

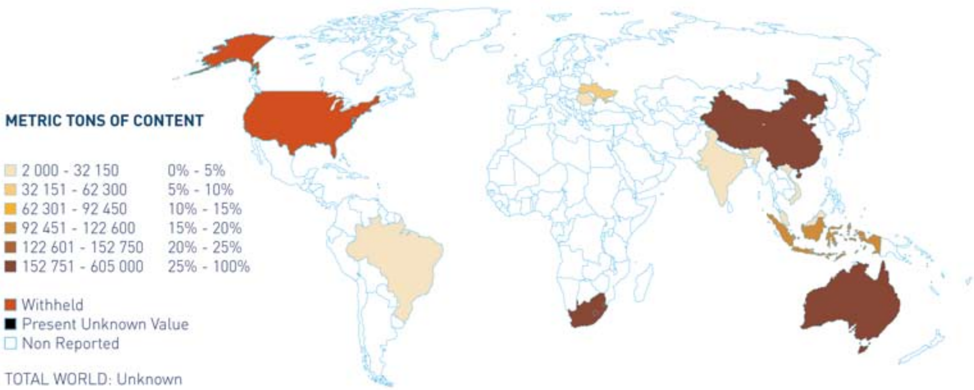


Figure 62. GLOBAL ZIRCONIUM PRODUCTION

Rare Earths

Characteristics and use

Rare earths is the group name of 17 chemical elements composed of yttrium, scandium and the lanthanides. The principal economic sources of rare earths are the minerals bastnasite, monazite, and loparite and the lateritic ion-adsorption clays. The rare earths elements range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements in the Earth's crust to thulium and lutetium, the least abundant rare-earth elements. The elemental forms of rare earths are iron gray to silvery lustrous metals that are typically soft, malleable, and ductile and usually reactive, especially at elevated temperatures or when finely divided. The rare earths' unique properties are used in a wide variety of applications.

Global reserves

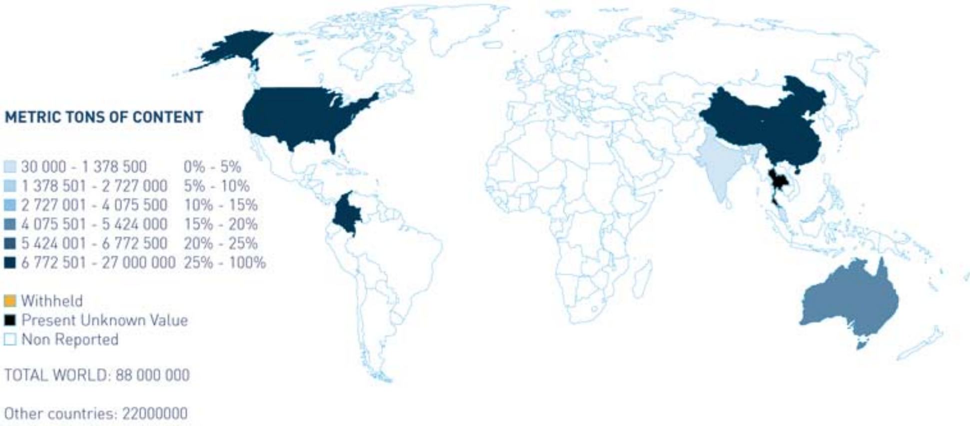


Figure 63. GLOBAL RARE EARTHS RESERVES

Production

Figure 64. GLOBAL RARE EARTHS PRODUCTION

Neodymium

Characteristics and use

Neodymium is a chemical element and a rare earth lanthanide metal. Its various compounds occur in trace amounts in minerals such as monazite and bastnäsite. Neodymium is a constituent of neodymium magnets used among other in motors and loudspeakers. As an additive in glass, it gives a red-purple colour used in lasers and infrared light. Furthermore neodymium is a key component of an alloy used to make high-power light-weight magnets for electrical motors in hybrid cars and in generators for wind turbines. Main extraction areas include China, the US, Brazil, India, Sri Lanka and Australia.

Neodymium compounds include neodymium aluminium borate used in optics and neodymium chloride used as the starting compound for the production of neodymium metal, in catalysis to form synthetic rubbers such as polybutylene and for corrosion protection.

Global reserves
No time series for global reserves available.

Production
No time series data for global production available.

Terbium
Characteristics and use
Terbium is a ductile and malleable rare earth metal and part of a group of 17 chemical elements composed also of scandium and the lanthanides called the rare earths. The principal economic sources of rare earths are the minerals bastnasite, monazite, and loparite and the lateritic ion-adsorption clays. Terbium is as such never found in nature as a free element, but it is contained in many minerals, including cerite, gadolinite, and monazite. The uses of terbium includes doping calcium fluoride, calcium tungstate and strontium molybdate materials that are used in solid-state devices. It is also used as a crystal stabilizer of fuel cells which operate at elevated temperatures. As a component of terfenol-D (an alloy which expands and contracts in magnetic field more than any other alloy), terbium is of use in actuators, in naval sonar systems and in sensors.

Global reserves
No time series for global reserves available. See reserve data for the rare earths.

Production
No time series for global production available.

Yttrium
Characteristics and use
Yttrium is part of a group of 17 chemical elements composed also of scandium and the lanthanides called the rare earths. Yttrium is never found in nature as a free element. The principal economic sources of rare earths are the minerals bastnasite, monazite, and loparite and the lateritic ion-adsorption clays. The rare earths elements range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements in the Earth's crust to thulium and lutetium, the least abundant rare-earth elements. The elemental forms of rare earths are iron gray to silvery lustrous metals that are typically soft, malleable, and ductile and usually reactive, especially at elevated temperatures or when finely divided. The rare earths' unique properties are used in a wide variety of

applications. The most important use of yttrium is in making phosphors such as the red ones used in television cathode ray tube displays and in LEDs. Other uses include the production of electrodes, electrolytes, electronic filters, lasers and superconductors; various medical applications; and as traces in various materials to enhance their properties.

Global reserves

Figure 65. GLOBAL YTTRIUM RESERVES

Production

No time series data for global production available. See production data for the rare earths.

A.3 Precious metals

Platinum Group Metals

Characteristics and use

Platinum group metals, or PGMs, consist of six chemical elements, namely platinum, palladium, iridium, osmium, rhodium and ruthenium. Chemically, they are all very similar but their physical properties vary considerably. Platinum, iridium and osmium are the densest known metals. Platinum and palladium are highly resistant to heat and to corrosion and are soft and ductile. Rhodium and iridium are more difficult to work and ruthenium and osmium are almost unworkable. Most commonly PGMs are alloyed with one another or other metals. This is also how they are found in nature.

PGMs can all act as catalysts, something which makes them suitable in many industrial applications. Of the six, platinum and palladium are of greatest commercial significance followed by rhodium. PGMs are sold in a number of forms, including pure metal and variety of compounds, solutions and fabricated products. It is the catalytic properties of the PGMs which act as basis for their applications in primarily two sectors: emission control systems (i.e. auto catalysts) and process catalysts (for industrial applications).

Global reserves

Figure 66. GLOBAL PGM RESERVES

Production

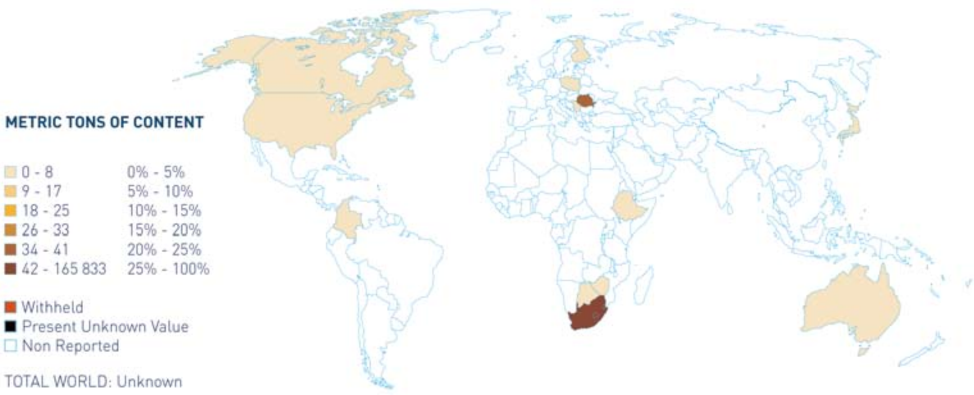


Figure 67. GLOBAL PLATINUM PRODUCTION

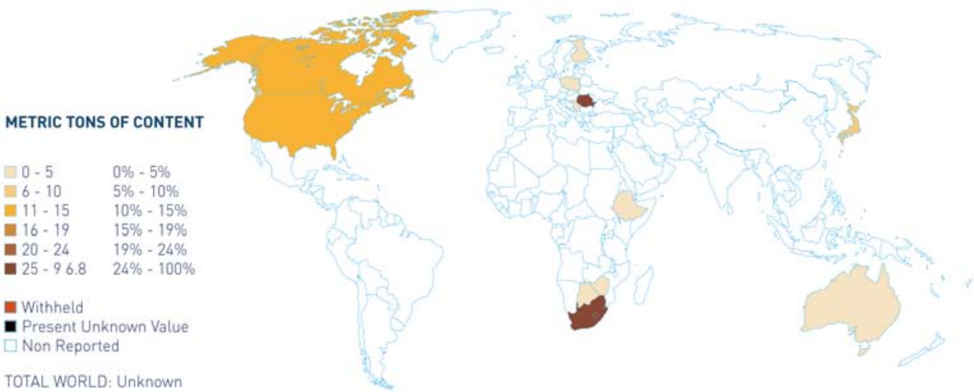


Figure 68. GLOBAL PALLADIUM PRODUCTION

Figure 69. GLOBAL OTHER PGM PRODUCTION

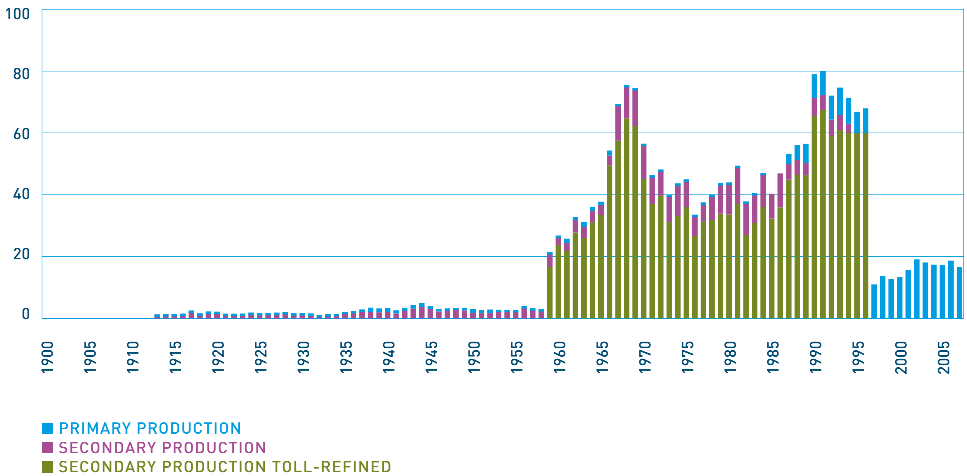


Figure 65. TOTAL US PGM SECONDARY PRODUCTION PROPORTIONATE TO PRIMARY PRODUCTION

US primary production of Platinum Group Metals[58] has compared to secondary production been relatively low, increasing only from the mid 1980's. US secondary PGM production took of in 1913 and has since experienced a rather stable secondary production with all time highs from the mid 1960's to the mid 1980's. What is of course noticeable is the substantial amount of recycling through secondary production toll refined. A significant dip is noticed here between 1965 and 1975, where former strength is not fully regained until 1990. From 1994 there is no available data on recycling.

Exploration for PGM in the US more or less ceased in the early 1900's mainly due to the availability of foreign supplies and the lack of applicable geologic, geothermal, and geophysical techniques for finding new deposits. It was not until the 1960's that these techniques were refined enough to determine PGM occurrence in geological material. This explains the generally low rates of primary production and the take off of PGM secondary production around 1913. Another possible explanation lays in the value of platinum at the time being nearly eight times as valuable as gold in 1920.[59]

Recycling of PGM is, as recycling is in general, dependant on the amount of recyclable materials within which the metal has been used. Hence, when the weight of platinum recovered from spent catalytic converters climbs, world secondary production increased as well. Growth like this is driven partly by an increase in average metal loadings of the catalysts being collected and partly by the high metal prices which encourages the recycling industry to process stocks it has previously hoarded.[60] The same holds true for ruthenium as 'the fate of the ruthenium market is closely tied to that of the electronics sector. With consumer and business purchasing of electronic goods currently weak, gross ruthenium demand is expected to soften. Additionally, the sector is likely to be able to meet most of its ruthenium requirements for the production of hard disks by using metal recycled from its own manufacturing processes. At current price levels, it remains attractive to recycle much of the scrap produced in the manufacture of hard disks. However, at prices significantly below this, recycling becomes less

58 Platinum Group Metals (PGM) consists of the metals platinum, iridium, osmium, palladium, rhodium and ruthenium.

59 The PGM Database, http://www.platinummetalsreview.com/jmpgm/index.jsp

60 Jollie, David (2009), Platinum 2009. Johnson Matthey, http://www.platinum.matthey.com/uploaded_files/Pt2009/09completepublication.pdf.

attractive than purchasing new metal'.[61] As the largest end-use of PGM is in auto catalysts followed by electrical and electronics the upward trend of PGM, the upward trend of PGM use can be presumed to continue. Secondary production, especially toll refined, should also become/be an important factor based on this same argument.

61 Ibid., p.13.

Annex B: International organisations

National mineral policies enfold within a broader international context. Within this context, numerous organisations have issued statements and established cooperative frameworks addressing mineral scarcity and security of supply. Annex D lists the main findings of an analysis of the interest statements and (co-operative) frameworks issued and initiated by the United Nations (UN) through the United Nations Conference on Trade and Development (UNCTAD) and the United Nations Environmental Programme (UNEP); the World Trade Organization (WTO); The Group of Eight (G8); The Group of 20 (G20); Organisation for Economic Co-Operation and Development (OECD); Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF); and International Council on Mining and Minerals (ICMM).

United Nations Conference on Trade and Development/ Special Unit on Commodities (UNCTAD/SUC)

The UNCTAD Special Unit on Commodities (SUC) clearly recognises mineral scarcity and security of supply to be an important part of its agenda. Since the overall goal of UNCTAD´s programmes on International Commodities Trade is to promote the development of developing countries through international trade, the SUC was established pursuant to the Accra Accord.[62] Through the Accra Accord, UNCTAD and SUC formally received a mandate to set up an active working programme within the field of minerals. The working programme aims to improve the capacity of commodity-dependent developing countries so to harness development gains from trade in commodities and to enhance international cooperation (within the mandate of UNCTAD) to address trade and development problems associated with the commodity economy. In accordance

62 The Accra Accord was affirmed in Accra, Ghana, in 2008 addressing the opportunities and challenges of globalisation for development as seen by the UN and UNCTAD and states the UN and UNCTAD action plans for the period 2008-2011 in regards to commodities trade; mineral trade, security and scarcity are a part of this plan.

with the SUC biennium 2010-2011, SUC shall provide advisory services, training courses, seminars and workshops and field projects. Hereby SUC hopes, amongst other things, to induce an integration of commodity/minerals strategies into the national development plans of developing countries.[63] Hence, UNCTAD/SUC has no formal mineral scarcity and security of supply policy, but a clear agenda working with several programmes and publications.

In the UNCTAD *Trade and Development Report 2009*,[64] the primary discussion centres on the effects of the financial crisis vis à vis commodities as a whole of which minerals are one part. The report discusses the fluctuations in trade and in commodity prices where the minerals market as a result of the financial crisis has stagnated. Prices have sunk and demand as well although estimates are that prices and demand will rebound as the crisis passes.

In the UNCTAD *World Investment Report 2007*,[65] the issue of mineral scarcity and security of supply incorporates four main features: 1) the overall evolving role of minerals in the world economy and the shifting centre of gravity of supply and demand towards developing countries; 2) the increasing role of transnational corporations (TNCs) in the extractive industries; 3) the implications for the development of host countries in regards to the altered mineral trade balance; and 4) the policy challenges that lie ahead.

63 For further implementation strategies of the Accra Accord in relation to commodities in general and minerals specifically, see United Nations Conference on Trade and Development (2008), Work plan for 2008–2011 for the Implementation of the Accra Accord, pp. 32 -36; and United Nations Conference on Trade and Development (2009), Commodity Policy Implementation and Outreach, http://www.unctad.info/en/Special-Unit-on-Commodities/Areas-of-Work/Minerals-Metals-Energy/.

64 United Nations Conference on Trade and Development (2009), Trade and Development Report, 2009.

65 United Nations Conference on Trade and Development (2007), World Investment Report 2007: Transnational Corporations, Extractive Industries and Development, pp. 108-323.

On a final note, UNCTAD has published, and continuously publishes, several research papers under its programme of activities on sustainable, resource-based development.[66]

United Nations Environmental Programme (UNEP)

UNEP also recognises mineral scarcity and security of supply as an important part of its agenda, especially in light of increasing global demand and decreasing global supply, which it views through an environmental lens. UNEP has no clear policy on mineral scarcity or security of supply, but has worked and is currently working on various programmes and assessment reports in this field.[67] One such programme is the International Panel for Sustainable Resource Management initiated in 2007. The programme aims to provide the scientific impetus for decoupling economic growth and resource use from environmental degradation. The overall objective of the resource panel is then to provide independent scientific assessment of the environmental impacts due to the use of resources over the full life cycle, and advise governments and organisations on ways to reduce these impacts.[68]

Another such programme is the E-waste Management Programme. E-waste is a generic term that encompasses old, end-of-life electronic and electrical equipment (EEE).[69] As examples, UNEP brings forward the necessity to recycle e-waste such as lead and cadmium in circuit boards; lead oxide and cadmium in monitor cathode ray tubes; and mercury in switches and flat screen monitors is recognised and encouraged. E-waste is recognised as valuable as it often contains precious and strategic metals and other high-tech materials that,

66 Of particular interest, we note Otto, J.M. (1998), 'Mineral Policy, Legislation and Regulation.' Mining, Environment and Development, UNCTAD Occasional Paper Series, No. 4; Pring, G.W. (1999), 'International Law and Mineral Resources.' Mining, Environment and Development, UNCTAD Occasional Paper Series, No. 2; Luque, S. (2000), 'Geographic Information Systems for Mineral Resources.' Mining, Environment and Development, UNCTAD Occasional Paper Series, No. 8; and Auty, R.M. (2000), 'The Geopolitics of Mineral Resources.' Mining, Environment and Development, UNCTAD Occasional Paper Series, No. 1.

67 United Nations Environmental Program (2009), Metals & Minerals. UNEP Division of Technology, Industry and Economics, http://www.unep.fr/scp/metals/.

68 United Nations Environmental Program (2009), Resource Panel. UNEP Division of Technology, Industry and Economics, http://www.unep.fr/scp/rpanel/.

69 United Nations Environmental Program (2009), E-Waste Management. UNEP Division of Technology, Industry and Economics, http://www.unep.fr/scp/waste/ewm/.

in an era of increasing scarcity, need to be recycled. Through the E-waste programme, UNEP strives to create awareness and a sufficient knowledge base in developing countries.

World Trade Organization (WTO)

The WTO has no current policy in regards to natural resources/scarce minerals/security of supply but is in the process of formulating policy in response to international developments.

The Group of Eight (G8)

The G8 policy on raw materials is formulated in the G8 Summit Declaration from 2007, *Growth and Responsibility in the World Economy*.[70] The policy centres on increased transparency and good governance instruments with regard both to the extractive sector as well as the subsequent trade and financial flows through several measures.

Furthermore, in 2004 the Group of Eight launched a new initiative, the so called 3R Initiative. It aims to promote the '3Rs' (reduce, reuse and recycle) globally so as to build a sound material cycle society through the effective use of resources and materials. Reducing refers to using materials with care to reduce the amount of waste generated. Reusing involves the repeated use of items or parts of items which still contain usable elements. Recycling refers to the use of waste itself as a resource. Waste minimisation can be achieved in an efficient way by focusing primarily on the first of the 3Rs, 'reduce,' followed by 'reuse' and then 'recycle'.[71] The Group of Eight member countries have committed themselves through the initiative to formulate national policies accordingly.

The Group of Twenty (G20)

G20 focuses on mineral markets, reflecting upon the importance of resource consumption, production, investment and trade to the world economy. G20 furthermore recognises that the gap between global demand and supply results in significant price fluctuations. At the annual G20 meeting in Melbourne in 2006, an official G20 work package with regards to energy and mineral resources was agreed upon, which can be referred to as G20 official policy. G20 agreed on

70 G8 (2007), Growth and Responsibility in the World Economy. Summit Declaration, p. 29 ff.

71 Japan Ministry of the Environment (2004), The 3R Initiative. http://www.env.go.jp/recycle/3r/en/outline.html

enhancing global trade to ensure sustainability and encourage efficiency; committed to direct domestic policies towards creating favourable overall investment climates and enhancing domestic and international competition; strived to establish principles for the efficient and effective governance of extractive firms, both private and state-owned; develop clear principles to guide trade and investment for extractive industries; and continue to enhance dialogue between producers and consumers.[72]

Organisation for Economic Co-Operation and Development (OECD)

OECD refers to the sustainable use of material resources as today's most challenging waste issue; promoting the sustainable use of materials to reduce their negative environmental impacts and to encourage waste minimisation, while supporting economic development, herewith is the OECD main focus.[73] To encourage waste prevention and minimisation and to manage materials in a sustainable manner, the OECD is developing policies and tools in several areas.[74] Against the background of the OECD Environmental Strategy[75] adopted by OECD Environment Ministers in 2000, OECD in 2004 initiated Sustainable Materials Management (SMM). The programme considers wastes as potential resources that can be used as inputs for new products hereby resulting in less virgin material extraction with related reduction of negative environmental impacts, less disposal and often less processing of waste.[76]

In 2004, the OECD Council adopted a Recommendation on the Environmentally Sound Management of Waste, ESM. The background was the varying scope and level of ESM implementation from one member country to another as well as the practice of waste dumping: shipments of wastes destined for recovery to OECD

72 G20 Meeting of Finance Ministers and Central Bank Governors (2006), Communiqué.

73 Organisation for Economic Co-operation and Development (2009), Waste. http://www.oecd.org/topic/0,2686,en_2649_34395_1_1_1_1_37465,00.html

74 Ibid. OECD has also published the Environmental Outlook to 2030 which makes for interesting reading in regards to OECD general environmental strategy. See Organisation for Economic Co-operation and Development (2008), OECD Environmental Outlook to 2030. http://www.oecd.org/environment/outlookto2030.

75 Organisation for Economic Co-operation and Development (2001), OECD Environmental Strategy for the First Decade of the 21st Century.

76 Organisation for Economic Co-operation and Development (2009), Sustainable Materials Management. http://www.oecd.org/document/62/0,33 43,fr_2649_34395_37895358_1_1_1_1,00.html.

countries and/or waste management facilities were directed to countries outside OECD with lower waste management standards. Imports and exports of waste destined for recovery within the OECD area are subject to a control system which has been developed by the OECD on the basis of a legal Act Decision C (2001)107[77] allowing trade of recyclable materials in an environmentally safe manner.

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF)

IGF is a global intergovernmental policy forum in the mining/metal sector and an outcome of the World Summit on Sustainable Development (WSSD) in Johannesburg 2002 and the Global Dialogue Initiative that was launched at the same meeting. The Global Dialogue was issued to implement the Johannesburg World Summit Plan of Implementation on sustainable development of the minerals and mining sectors. The Forum is an extension of the Dialogue.[78]The Johannesburg World Summit Plan of Implementation states three key areas of attention in regards to the extraction industries:[79] 1) promoting transparency and accountability for sustainable mining and minerals development; 2) enhancing of participatory actions involving stakeholders focusing on local and indigenous communities and taking into account significant transboundary impacts; and 3) focusing on capacity building support to developing countries and countries with economies in transition, including value added processing.

International Council on Mining and Minerals (ICMM)

ICMM is a CEO-led industry group that addresses key priorities and emerging issues within the international mining and minerals sector. With respect to mineral scarcity and security of supply, ICMM has co-operated with several other international organisations in a number of co-operative projects and work programmes.[80] In 2002 ICMM and UK Government launched the Extractive

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77 Organisation for Economic Co-operation and Development (2001), Revision of Decision C(92)39/FINAL on the Control of Transboundary Movements of Wastes Destined for Recovery Operations.

78 The Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development IGF (2009), A Report for UNCSD 18. http://www.globaldialogue.info/Forum%20report%20to%20UNCSD3%20_2_.pdf.

79 Ibid., p. 11.

80 International Council on Mining and Metals (2010), Who We Work With. http://www.icmm.com/our-work/who-we-work-with.

Industries Transparency Initiative (EITI) to increase transparency over payments by companies to governments and government-linked entities.[81] In 2004, ICMM, the World Bank and UNCTAD released the Resource Endowment Guide *The Challenge of Mineral Wealth: Using Resource Endowments to Foster Sustainable Development*.[82] In 2004 and 2006 respectively, ICMM and the World Conservation Union, IUCN, published several guides on the conservation of biodiversity in relation to mining and by member countries and IUCN signed the Memorandum of Understanding on the Conservation of Resource and Mineral Reserves.[83]
On a final note, in 2004 and 2008 respectively, ICMM and the Oil, Gas and Mining Sustainable Community Development Fund, CommDev, published recommendations on Sustainable Development, Knowledge Base Development and Capacity Building Development including several workshops and a number of other publications.[84]

81 Extractive Industries Transparancy Initiative (2009), EITI Fact Sheet. http://www.eitransparency.org/files/2010-01-25%20EITI%20Fact%20Sheet.pdf.

82 McPhail, K. (2009), 'The Challenge of Mineral Wealth: Using Resource Endowments to Foster Sustainable Development,' in Richards, J. Mining, Society and a Sustainable World. Berlin: Springer.

83 International Council on Mining and Metals (2010), Who We Work With: IUCN – ICMM Dialogue. http://www.icmm.com/page/1672/iucn-icmm-dialogue.

84 International Council on Mining and Metals (2010), Who We Work With: World Bank/IFC/CommDev. http://www.icmm.com/page/1655/world-bank/ifc/commdev. See for example Energy Sector Management Assistance Programme, the World Bank and the International Council on Mining and Metals (2005), Community Development Toolkit.

Annex C: Definitions policy related measures

Through this report different definitions have been used for policy related measures. These definitions are listed in this annex.

National governance

Domestic Supplier Preference refers to government policy to acquire minerals from national businesses in order to stimulate national businesses.

Direct State Involvement refers to active government participation in the private sector and direct support to business negotiations with third parties.

National Coherent Government Policy(-ies) refer to inter- en intra-agency cooperation within a country.

National Transparency refers to encouragement and/ or creation of transparent political rules and regulations and transparent business models on a national level.

National Good Governance refers to the good conduct in public affairs, management of public resources, and guaranteeing the realization of human rights on a national level.

Public-Private Partnerships refers to an agreement between a federal, state, or local agency (public entity) and a private-sector organization with the objective to leverage the collective expertise and resources to positively impact an issue that benefits the public at large[85].

85 United States Chamber of Commerce (2009), Glossary. http://www.uschamber.com/bclc/programs/disaster/2008_disasterreport_glossary.htm.

National Enterprise Preference refers to nationalized mining enterprises and mineral extraction, including increased nationalization of previous private enterprises.

Private Enterprise Preference refers to privatized mining and mineral extraction, including increased privatization of previous national enterprises.

Trade Restriction

Tariffs refer to the use of government tax on imports or exports.

Import Restrictions refer to policies limiting the amount of certain minerals allowed to be imported.

Export Restrictions refer to policies limiting the amount of certain minerals allowed to be exported.

Direct- and Export Subsidies refer to grants or financial assistance given by the government either directly to a business (sector) or to a specific mineral in order to lower the market price.

Layered Exchange Rates refer to artificially or non-market based currency values.

Administrative Barriers refer to usage of specific national rules and regulations by the government in order to create impediments for access to the internal market.

Anti-Dumping Policies refer to acts of manufacturers or governments to sell minerals at a price which is either below the price it charges in its home market or is below its costs of production in order to gain a stronger market position.

Technology Advancement

Renewable Energy refers to policy encouraging the development of technology to obtain energy from sources that are essentially inexhaustible, such as wood, waste, geothermal, wind, photovoltaic, and solar thermal energy.

Recycling refers to policies encouraging the collection and processing of materials suitable for recycling as well as encouraging the development of more efficient recycling techniques.

Minerals Substitutes refers to policies encouraging development and research in searching substitutes for (critical and scarce) minerals.

Research and Development (R&D) refers to policies encouraging research and development with regard to mineral extraction, processing or usage.

Domestic Capacity Improvement refers to policies improving the national resource, industrial, technological or academic capacities.

Knowledge Base Improvement refers to policies encouraging the improvement of the knowledge of existing sources, reserves and usage of minerals.

Pro-active Acquisition

Identification of Critical Minerals refers to policies actively identifying minerals vital for national security and industries.

Stockpiling of Critical Minerals refers to the creation or maintaining stocks of minerals deemed vital for national security and industries.

International Strategic Partnerships refer to the closing of bilateral partnerships and allying with other countries in order to guarantee a security of supply.

Foreign Direct Investment refers to (non-)aggressive buy-ins through strategic investments in foreign enterprises and/ or the acquisition of foreign enterprises or concessions.

Development Cooperation category

Development Aid refers to aid given by governments and other agencies to support the economic, social and political development of developing countries.

Transparency refers to the encouragement and/ or creation of transparent political rules and regulations and transparent business models in a third country, including for example mining law and extraction policies.

Good Governance refers to the encouragement of good conduct in public affairs, management of public resources, and guaranteeing the realization of human rights by national governments in third countries.

Global Governance category

Liberalization efforts of World Markets refer to relaxation of government restrictions focusing trade- and capital market liberalization, in particular with regard to WTO rules and regulations.

Global Governance refers to policies encouraging and/ or creating rules, regulations and institutions on an international multilateral level.

Annex D: Glossary

Based on definitions of the USGS.

Resource
A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Identified Resources
Resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence are considered identified. Identified resources include economic, marginally economic, and sub-economic components. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into measured, indicated, and inferred.

Demonstrated
A term for the sum of measured plus indicated.

Measured
Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated
Quantity and grade and(or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred
Estimates are based on an assumed continuity beyond measured and(or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Sub economic Resources
The part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Undiscovered Resources
Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or sub economic. To reflect varying degrees of geologic certainty, undiscovered resources may be divided into two parts: Hypothetical Resources. – undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources
Undiscovered resources that may occur either in known types of deposits in favourable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Reserve Base
That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass 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. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently

sub economic (sub economic resources). The term 'geologic reserve' has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.

Inferred Reserve Base

The in-place part of an identified resources from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit and for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence.

Reserves

That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as 'extractable reserves' and 'recoverable reserves' are redundant and are not a part of this classification system.

Marginal Reserves

That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technological factors.

Economic

This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Restricted Resources/Reserves

That part of any resource/reserve category that is restricted from extraction by laws or regulations. For example, restricted reserves meet all the requirements of reserves except that they are restricted from extraction by laws or regulations.

Other Occurrences

Materials that are too low grade or for other reasons are not considered potentially economic, in the same sense as the defined resource, may be recognized and their magnitude estimated, but they are not classified as resources. A separate category, labelled other occurrences, is included in figures 1 and 2. In figure 1, the boundary between sub economic and other occurrences is limited by the concept of current or potential feasibility of economic production, which is required by the definition of a resource. The boundary is obviously uncertain, but limits may be specified in terms of grade, quality, thickness, depth, percent extractable, or other economic-feasibility variables.

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Jaakko Kooroshy is a policy analysts focusing on the global economy and geopolitics. He has expertise in a range of quantitative and qualitative research methods and scenario development. In previous work he has contributed to a wide variety of global policy debates, including water scarcity, labor market institutions, FDI in the public sector of developing countries, and conflicts in the Middle East.

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Minerals are an indispensable material pillar of our current technologies, economies and societies. Due to a rapid expansion of the world economy and many new high-tech applications, demand for minerals has been exploding in recent years, while mining has struggled to keep pace. This has led to fierce global competition between countries and companies over scarce mineral resources – and a number of high-tech elements in particular. Prices have skyrocketed and countries have created strategic stockpiles or imposed export restrictions, in order to secure supplies of these valuable resources that are often the key to advanced technologies. As minerals are getting evermore difficult to find and costly to extract, some experts have even warned that we might run out of specific metals altogether.

This report on scarce minerals provides an in-depth analysis of trends in global mineral markets and the policies that major producer and consumer countries have devised in order to deal with mineral scarcity. It not only provides insight into how scarce minerals actually are, but examines the international security implications and geopolitical consequences of scarce mineral resources. As such it is indispensable reading for experts and policymakers concerned with scarcity of natural resources on our planet.

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