



STRATEGY  
& CHANGE

# RARE EARTH ELEMENTS AND STRATEGIC MINERAL POLICY

*THE HAGUE CENTRE FOR STRATEGIC STUDIES AND TNO*



## STRATEGY & CHANGE

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& CHANGE

RARE EARTH ELEMENTS AND STRATEGIC MINERAL POLICY

*THE HAGUE* CENTRE FOR STRATEGIC STUDIES (HCSS) AND TNO

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# INTRODUCTION

Newspapers report almost daily on international tensions around 'strategic' or 'critical' minerals such as rare earth elements. The temporary freeze of rare earths exports from China to Japan in retaliation of the capture of a Chinese captain near the disputed Senkaku islands in the East China Sea is but one example of the strategic use of non-fuel minerals in international relations today. Ensuring and safeguarding access to rare earth elements and other strategic mineral resources is quickly emerging as a strategic policy priority and a number of states are designing and implementing new policies aimed at increasing material security. By analyzing the strategic mineral policies of three countries, the United States, the United Kingdom and Japan, this report provides an insight into what drives policies on strategic non-fuel mineral resources.

Mineral policies do not developed in a vacuum. Therefore, this report consists of three parts. Before analyzing individual countries' mineral policies, the first chapter examines the conceptual context in which policies on strategic non-fuel minerals (i.e. mineral resources other than hydrocarbons) take shape and emphasizes the important role of economic and policy factors.

The following chapter analyzes the development of strategic mineral policy of three advanced economies located in three different continents: the US, the UK and Japan. These chapters form the heart of this report. They are the first of a larger set of case studies that the Hague Centre for Strategic Studies (HCSS) intends to develop as part of our ongoing research on strategic mineral resources. The US, UK and Japan have been selected because these countries are all (a) advanced, industrialized economies, which (b) depend on the free global flow of minerals resources for the supply of their economies and (c) have very different policies towards strategic non-fuel minerals, both in terms of key strategic concerns and the policy instruments they use.



Thirdly, in the Annex, this report provides a comprehensive overview of 37 metals that are considered strategic non-fuel minerals by some countries. The list includes well-known base metals like copper or nickel as well as less known minerals like beryllium or hafnium. For each of these chemical elements, we provide key producing countries and their reserves, their main physical properties, key technical applications and information about the extent to which these mineral resources are currently being recycled.

Our analysis shows that the strategic value of non-fuel mineral resources stems from two factors. First, these resources possess properties that make them essential to key applications and technologies in defense, aerospace and (green) energy industries. Second, the supply of these resources is vulnerable to disruptions. This vulnerability may be due to the absence of a transparent market and limited production or to geopolitical tensions associated with the supply or sourcing of these materials from a limited number of countries with a disproportionate share in global production.

Concern over access to strategic non-fuel mineral resources is not a new phenomenon. The country analyzes provide historical context to the current discussion over material security. They deal with previous periods marked by heightened concerns over the supply and access to specific mineral resources; and discuss strategies that have been used in the past to address these insecurities. These historical examples also demonstrate that the policy debates that have taken place in the past are quite similar to the discussions we are witnessing today, for example with respect to rare earth elements. However, as the geography of production, technologies, and international relations change over time, different mineral resources attract the focus of policy-makers. While rare earth elements currently dominate the policy agenda, other strategic non-fuel minerals, for example platinum group metals, were considered to be of 'strategic' importance in the past. Strategic concerns also vary considerably from country to country.

This report provides valuable data and insights that contribute to a better understanding of the tensions that arise around rare earth elements and other strategic non-fuel minerals. The analysis provided in the report may also offer a basis for more informed policy-making in those countries that are currently considering policy options on strategic non-fuel minerals.

# 1 CONTEXTUALIZING MINERAL POLICY

National policies towards non-fuel minerals are typically motivated by a variety of issues—ranging from the goal of ensuring a reliable and affordable supply of raw materials to domestic industries to making the most out of a country's resource endowments. Not surprisingly, these policies are shaped to a considerable extent by the prevailing economic and material realities in which they emerge. For example, countries with extensive industrial production and high demand for raw materials are likely to differ in their approach to supply security from other countries with a mainly services-oriented industry. Similarly, countries with a strong mining sector will rely on a different set of policies than those which are mainly import dependent for minerals.

The questions of 'who has what and who needs what?' are essential to understanding policies. But they are often much more difficult to answer than it would appear from looking at popular metrics such as import dependence, annual production or reserves. Newspaper accounts on minerals are often filled with impressive numbers stating that the European Union (EU) is 100% import dependent for niobium and platinum, that China produces 97% of rare earths, or that Bolivia holds the world's largest lithium reserves. The intricate economic configurations these numbers describe are however often much more complex than the simple physical realities they appear to suggest.

Before examining different mineral policies, it thus pays to pause and shortly consider the physical and economic contexts in which mineral production and consumption takes place – a task that is picked up in the remainder of this chapter.

### 1.1 THE STATIC PARADIGM

The public debate on minerals, like similar debates on fossil fuels, is dominated by an often implicit, intuitive conception of natural resources, which may be referred to as the static paradigm.<sup>1</sup> The key assumptions of this paradigm are straightforward: there is a fixed, even if not necessarily exactly known amount of resources on the planet. Ongoing mining and consumption of these mineral resources diminishes these finite reserves, with the speed of extraction and consumption determining the rate of depletion. When cumulative human consumption has depleted reserves to the degree that existing deposits are being exhausted and new ones are even smaller and even more difficult to find, production begins to struggle to meet demand. A Malthusian endgame-scenario is the ultimate consequence, as consumers scramble to secure the little that is left. Prices skyrocket and supply shortages rock markets, as fierce conflicts ensue over the control of residual reserves.

The key metric in this static conception is the so-called static range, which is the estimate of time left until depletion of a given non-renewable resource. 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. Table 2 shows a number of estimates of static ranges for several different elements.<sup>2</sup>



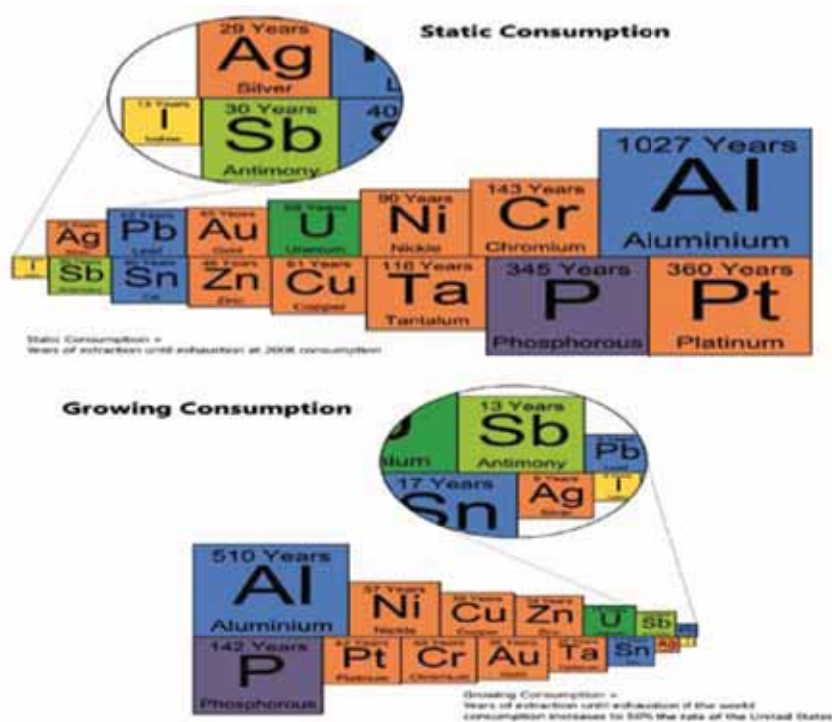


FIGURE 1. STATIC RANGES, A MISLEADING MEASURE

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

From this perspective, the scope of mineral policy is fairly limited. Exploitation rates might be increased or lowered (e.g. by subsidising mining, taxing consumption, or intensifying exploration), stockpiles may be created or exports may be reduced, but there is little room for policy to significantly alter the context in which it takes place.

1.2 THE DYNAMIC-ADAPTIVE PARADIGM

The static paradigm has dominated much of the public debate on resource policy because it is intuitive, logically coherent, and allows for clear-cut conclusions and policy-recommendations. However, it is imperative to understand that the static paradigm suffers from a number of fundamental conceptual flaws that do not allow it to adequately capture the much more complex reality of global mineral production and consumption.

The most powerful indication of the static paradigm’s shortcomings comes from the reserve data for different elements, which provide the basis for estimates of static ranges. Figure 2 shows that reserve figures have been fairly stable or even increasing at times, despite ongoing and constantly expanding production. This fact cannot be explained in the static paradigm. At most, the latter might allow for occasional upward corrections 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.

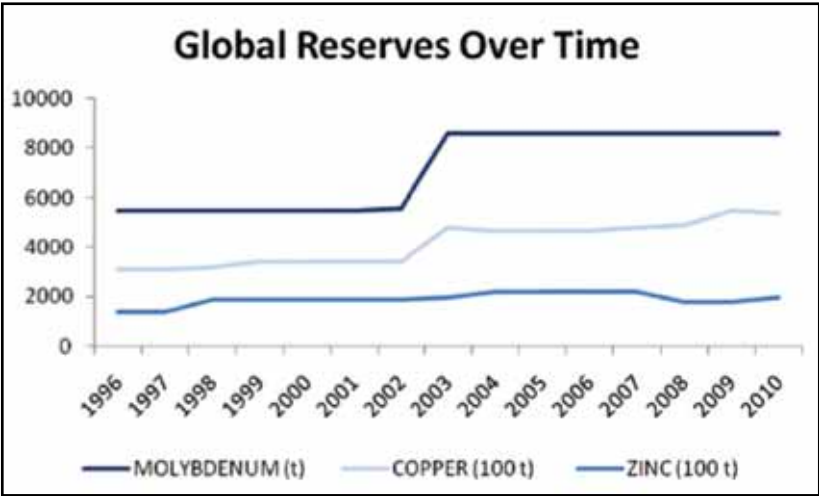


FIGURE 2. GLOBAL RESERVES OF THREE METALS OVER TIME.  
SOURCE: USGS MINERAL COMMODITY SUMMARIES, VARIOUS EDITIONS.

The explanation for this apparent contradiction lies in 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 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 grasp mineral policy. It does not imply that uneven reserve distributions are not an issue. However, it shows that who has what 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 because 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 in different countries. Reserve data change continuously in different countries and are subject to a wide range of factors, from changes in prices to advances in technology.

From this perspective, the scope for mineral policy is considerably broader. Mineral policy suddenly also concerns business and environmental regulations, trade and investment policies, and research into issues as diverse as exploration and extraction technologies, recycling methods and technical substitution. Simplistic policy recipes based on the supposed fact that ‘we are running out’ of this metal or another, have to give way to a much more nuanced analysis of the influence of policy on the economic, technological and geological constraints that structure global mineral supply.

### 1.3 HOW SCARCE ARE MINERALS ON THE PLANET?

Reserve data for a given element do not represent the total quantity present on the planet. As a matter of fact, the question of how much of a given element is physically present on the planet is of limited relevance for the policy debate. Even the scarcest elements invariably occur around the world. However, most of what exist of any given element 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 and thereby become available to the global economy.

### 1.4 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 the policy debate, then one may 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, based on the 118 elements of the periodic table, 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*.

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, mineral supply would thus be a non-issue.

## 1.5 HOW SCARCE ARE MINERALS THAT CAN BE MINED PROFITABLY?

Again, however, these benign numbers are irrelevant to the policy debate. The ability to access and collect the elements is of far greater relevance 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 concentrations* (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 which can vary from several hundred million to several billion Euros. 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 crust is between 10 and 50 km deep, but even the world's deepest mine, located in Johannesburg, South Africa, is 'only' 3.9 km deep.<sup>4</sup> 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 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 3).

It is part of the adaptive nature of the global economy that producers and consumers as well as national governments seek to adapt to changing availability and prices. As prices of products based on particular elements rise, consumers seek to reduce their consumption of these goods. Companies that manufacture such products seek to substitute these elements with more abundant ones if possible and direct their R&D departments to develop alternative products or inputs that rely on cheaper resources. Recycling will become more profitable and will increase in volume. These efforts could reduce demand for particularly sought-after mineral resources over time.

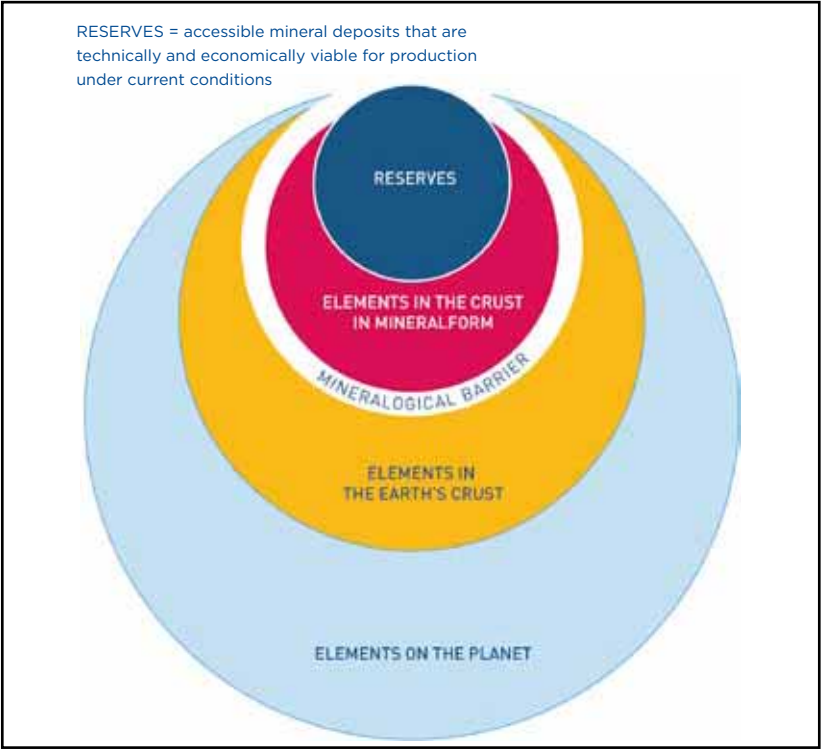


FIGURE 3. ELEMENTS ON THE PLANET

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 reserves and eventually output over time. Taken together, falling demand and increasing production in response to high prices will mitigate resource pressure to some degree. The system adapts.

However, sometimes 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 of many years. 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 resources.

This can lead at times to volatile, tight markets that are vulnerable to disruptions. Already small reductions in output quantities or increases in demand can lead to fierce price hikes and shortages. New restrictions such as export quotas or strategic stockpiles created by states that seek to secure supplies and protect national industries, can further complicate the picture.

The bottom line is that when examining policy on minerals 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 of 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 prices, technology and our knowledge of physical deposits evolves.

However, individual countries policies and preferences matter too. Reading the newspaper one might e.g. get the impression that the US depends on China for rare supply because the world's reserves are concentrated in the country by geological accident. However, the US was still the largest producer on the planet only two decades ago and the US Geological Survey (USGS) has recently estimated that there are roughly 12 million tonnes of rare earths in the US, much of which could be mined profitably<sup>5</sup> – enough to last the world for many years if necessary. Nonetheless, current annual US production of rare earths stands at zero tonnes in 2010.

These are facts that geologists and material scientists cannot explain. Instead, it takes insight into politics and policy, economics and business, as well as a good grip on the complex history of mining efforts both in China and the US to gain an understanding of what has happened and how policy might be able to change these facts on the ground. It is precisely this kind of understanding that we try to contribute to in the following chapter through a first set of case studies of national mineral policies.





## 2 COUNTRY MINERAL POLICY

### 2.1 INTRODUCTION

In this chapter the mineral policy of the US, the UK and of Japan are analyzed. Each survey will address the historic developments, the definitions that are used in the country for strategic minerals and the key policy actors concerned with them. Also currently emerging legislation and policy instruments will be discussed, after which a short summary is presented.

### 2.2 THE UNITED STATES

This section looks at the evolution of US policy regarding strategic and critical minerals. The US approach takes shape in response to geopolitical tensions and has a strong national security dimension. Historically, US responses to supply risks have been to emphasize subsidized domestic production and stockpiling. Contemporary policy appears to follow this trend.

#### BRIEF HISTORY

Increased concern over strategic minerals has historically been associated with geopolitical tensions. The US has a long history of involvement in the production and international exchange of minerals. Concurrent with growing import dependence, US policy makers have become concerned with the availability and supply of strategic minerals. This has produced several cycles of mineral concern over the decades.

In the mid-20<sup>th</sup> century, two major events – the Second World War (WWII) and the Korean War – heightened concern over strategic minerals. As tensions in Europe escalated in the run-up to WW II, the production of essential military equipment in the US appeared threatened by shortages of raw materials.<sup>6</sup> As a result, the Strategic Materials Act of 1939 established the National Defense Stockpile and authorized the government to determine the quality and quantity of strategic materials to be stockpiled.

The purpose of the National Defense Stockpile was to reduce the possibility of 'a dangerous and costly dependence by the US upon foreign sources for supplies of such materials in times of national emergency.'<sup>7</sup> These stockpiled materials could only be released in times of national emergency, when prices would be much higher and supplies constrained. The strategic rationale of the stockpile was that its existence would deter aggressors who hoped to challenge the US by cutting off its supplies and thereby incapacitate its defense industry.

After WW II however, concerns arose that if the large stockpile would be disbanded, mineral prices on world markets might be depressed for a considerable time. This led Congress to pass the 1946 Strategic and Critical Material Stockpiling Act, confirming its commitment to assure the adequate supply of materials in the event of a military emergency, effectively giving the stockpile a permanent status.<sup>8</sup> The stockpile came soon under pressure again, as the Korean War in 1950 created another period of strategic mineral shortages. In response, the Defense Production Act of 1950 authorized the government to subsidize the production of aluminium, copper, tungsten, and other metals through a \$2 billion loans program that was used to shore up the domestic mining industry.<sup>9</sup>

After the Korean War, the cost of maintaining domestic production altered the perception on import dependence and the usefulness of the National Defense Stockpile and subsidized domestic mining operations. It was argued that many strategic minerals should be procured abroad as domestically they could only be produced at costs far above world market prices.<sup>10</sup> The focus of US mineral policy shifted from a premium on reliability and national control to a concern for controlling costs. Reliance on a few lower-cost foreign sources increased.<sup>11</sup>

After a longer period of calm, concerns over the reliability of supply resurfaced again in the 1970s and 1980s. A sense of urgency was generated by the growing influence of the Soviet Union (USSR) on the mineral market. Changing its strategy, as one of the largest mineral producers, the USSR started importing from countries that traditionally traded minerals with the US and its Cold War allies. US policy makers feared that expanding Soviet influences among nations with large reserves of strategic minerals would lead to the Soviets cornering roughly 80% of the mineral market.<sup>12</sup> These

move by its primary competitor troubled Washington. Fears were further exacerbated during the energy crisis.<sup>13</sup> In 1973, oil producing states tried to restrict oil exports to the US in retaliation of its support for Israel. It led US experts to worry about similar economic coercion by the USSR through its control of strategic non-fuel minerals.

A national debate took shape over concerns of interrupted mineral exports and the possibility that foreign mineral producers would form an OPEC (Organization of the Petroleum Exporting Countries) -type cartel to raise mineral prices. At the same time, the crisis further increased US import dependence since rising oil prices made it more cost effective to refine and process minerals close to the mine, reducing transportation costs. With limited production capability at home, this meant increased dependence on foreign supplies and further increased concern over foreign political steps. The higher energy costs also led to a slump in the US economy, decreasing investments in new and more competitive manufacturing plants.<sup>14</sup>

In the wake of this first period of widespread commodity shortages after the Korean War, the National Commission on Supplies and Shortages was established with the Defense Production Act Amendment of 1974.<sup>15</sup> Focusing on US dependency on a limited number of suppliers, in 1976 the National Commission on Supply Shortages pointed out that supply risks resulted from the vulnerability of mining facilities and the politicization of minerals in southern Africa.<sup>16</sup>

US policy makers were particularly concerned about political unrest in South Africa and Zaire. The nature of the apartheid regime in South Africa, one of the world's dominant platinum-producers, confronted US policy makers with the dilemma that the US could be compelled to enforce an import embargo for political reasons, while being economically dependent on South African supplies of minerals. In 1978-1979, local instability and a political insurrection in Zaire caused a sharp drop in cobalt production resulting in shortages. Furthermore, proposals by developing countries to use mineral exports as part of an anti-Western 'New International Economic Order' reinforced the view that US policy makers had been injudicious in making the US dependent on unreliable suppliers.<sup>17</sup>

In its report to Congress of December 1976, the National Commission on Supplies and Shortages recommended that the US stockpile should be used to alleviate the danger of commodity shortages. Since the use of the National Defense Stockpile was restricted to defense emergencies, the National Commission on Supplies and Shortages suggested the creation of an economic stockpile. The economic stockpile could be used in case of severe supply disruptions due to other contingencies, such as local wars or disturbances in major supplier states, embargoes or cartels.<sup>18</sup>

Calls for more effective use of the stockpile and the possible creation of an economic stockpile were however met with strong opposition from the mining and metal producing community. They argued against using the strategic stockpile to influence market prices.<sup>19</sup> Making most of their profit when prices peak during national emergencies, companies seemed to prefer their chances on a volatile market rather than being subject to government intervention. This debate resulted in the Strategic and Critical Materials Stockpiling Revision Act of 1979. Its goal was to revise the Defense Stockpile Program, specifying that the stockpile was to be managed for defense purposes only and not to control commodity prices.<sup>20</sup>

In 1980 the National Materials and Minerals Policy, Research and Development Act, mandating the development of a national mineral policy, declared that 'that it is the continuing policy of the US to promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production.' Debate over the use of the stockpile to dampen the business cycle had not been settled yet in 1988 when the Pentagon became responsible for managing the National Defense Stockpile. The last time new materials were purchased for the National Defense Stockpile dates back to 1992, when the National Defense Stockpile Centre bought natural rubber, tantalum minerals and tantalum oxide.<sup>21</sup> At the end of the Cold War, the Department of Defense (DOD) decided that there was an excess of certain materials and directed a partial sale of the National Defense Stockpile.<sup>22</sup> This sales program continues to the present day, and has involved minerals including rare earth elements (REEs).

## US DEFINITION OF STRATEGIC NON-FUEL MINERALS

The US holds a strong security-centric perspective of its mineral policy. According to the Congressional Research Service, the current goal of US mineral policy is to promote an adequate, stable, and reliable supply of materials for US national security, economic well-being, and industrial production.<sup>23</sup> The US does not currently have an overarching national strategic policy document on non-fuel minerals. Before an elaboration on the different legislative proposals and other policy instruments is offered, a brief elaboration on the US definition of 'strategic minerals' is provided.

US policy documents addressing the issue of strategic non-fuel minerals employ different terminology and definitions. The terms 'critical minerals' and 'strategic minerals' are closely related but usually not clearly differentiated.<sup>24</sup> The terms entered the US policy lexicon with the *Strategic and Critical Materials Stock Piling Act in 1939*.<sup>25</sup> Its most recent update of 2005 defines 'strategic and critical materials' as materials 'that (a) would be needed to supply the military, industrial and essential civilian needs of the US during a national emergency, and (b) are not found or produced in the US in sufficient quantities to meet such need.'<sup>26</sup> This is a broad definition in which the strategic value of the materials derives both from their application and availability. Both terms are also employed more narrowly by the DOD Strategic Materials Protection Board. In its 2008 report, a 'material critical to national security' is defined as 'a strategic material for which (1) the DOD dominates the market for the material, (2) the Department's full and active involvement and support are necessary to sustain and shape the strategic direction of the market, and (3) there is significant and unacceptable risk of supply disruption to vulnerable US or qualified non-US suppliers.'<sup>27</sup>

More recently, the Under Secretary of Defense for Acquisition, defined strategic materials as 'those materials for which the US is largely import dependent, for which no viable economic substitute exists, or for which there is concern over the source (for geopolitical reasons) or the supply (for market reasons).'<sup>28</sup> This definition explicitly notes the importance of substitutes and underlines that concerns about supply restrictions can stem from both geopolitical and economic turmoil.

Although the definitions have different emphases and vary in scope, they generally identify the same factors that contribute to a mineral's criticality or strategic value. First, they refer to minerals that are important in use, either at the state level (national security or economy) or at the product level (the mineral performs a unique function and is therefore an essential input). Second, they allude to minerals whose availability is restrained in various ways. This can be caused by a lack of domestic reserves and production, high import dependency, or disruptions of supply originating with the supplier or the market. The absence of a viable substitute, due to high costs or technical difficulties, is a key determinant of both the importance of use and the availability.<sup>29</sup>

### US STRATEGIC MINERALS

The list of strategic non-fuel minerals of the US is dynamic yet shows some overlap over time. Reports from the 1970s-1980s list aluminium, chromium, cobalt, manganese, nickel, platinum-group metals (PGMs) and titanium as strategic minerals. Chromium, cobalt, manganese, and PGMs were considered most critical as a result of the political unrest in southern Africa from which the US imported almost all of its minerals.<sup>30</sup> According to the USGS these remain strategic minerals today due to their extensive use in the production of military assets and key sectors of the US economy, including the automotive, aerospace, electronic, chemical, glass and energy industries.<sup>31</sup>

It therefore comes as no surprise that these materials also appear in a 2008 report on critical minerals by the National Research Council (NRC). The NRC developed a methodology to evaluate the criticality of non-fuel minerals. Of those metals examined, the following were found to be critical: PGMs, REEs,<sup>32</sup> indium, manganese, and niobium. Criticality was based on the importance of their application, the difficulty of finding substitutes and the high associated supply risks. Other non-fuel minerals that were considered essential, though short of 'critical' included industrial and construction minerals including copper, bauxite and iron ore.<sup>33</sup>

One year later, in February 2009, the differentiation between essential, strategic and critical non-fuel minerals reappeared in a report by the Office of the Secretary of Defense and the Strategic Materials Protection Board on the national security issues associated with specialty metals. In this

report specialty metals were considered strategic for defense purposes, which means they may require special monitoring and attention from the DOD. However, they were not considered materials critical to national security for which the DOD is required take action to ensure long term domestic availability, such as stockpiling.

In a report to Congress on the reconfiguration of the National Defense Stockpile of April 2010 the DOD recommended the following 13 materials for stockpiling: beryllium metal, chromium metal, cobalt, columbium (niobium), ferro-chromium, ferro-manganese, germanium, iridium, platinum, tantalum, tin, tungsten, and zinc. The report's authors pointed out that the list of materials critical to the strategic defense interests of the US would change according to defense needs and market developments such as supply, price and quality.

1970s-80s Strategic Minerals ( W.C.J. van Rensburg)	2008 Critical Minerals (National Research Council)	2010 DOD Recommended Materials for National Defense Stockpile (Report to Congress)
Aluminium	Platinum Group Metals	Beryllium Metal
Chromium	Rare Earth Elements	Chromium Metal
Cobalt	Indium	Cobalt
Manganese	Manganese	Columbium (Niobium)
Nickel	Niobium	Ferro Chromium
Platinum Group Metals		Ferro Manganese
Titanium		Germanium
		Iridium
		Platinum
		Tantalum
		Tin
		Tungsten
		Zinc

FIGURE 4 STRATEGIC AND CRITICAL MINERALS

Three decades ago the criticality of certain strategic non-fuel minerals was raised due to concerns about reliability of African suppliers. In a similar fashion, the current import dependency on China's near-monopolistic supply of REEs has contributed to heightened concerns about this group of materials. REEs and other rare metals are important to the DOD due to

their important functions in defense applications, such as jet-fighter engines, missile guidance systems, antimissile defense, and space-based satellites and communication systems.<sup>34</sup> In particular, the DOD considers alnico, ferrites, samarium-cobalt, neodymium-iron-boron and high purity beryllium essential because of their unique properties.<sup>35</sup> Samarium cobalt and neodymium-iron-boron are REE-alloys and are used to produce the world's strongest permanent magnets, essential for many military applications. High purity beryllium is used in sensors, missiles, satellites, avionics and nuclear weapons.<sup>36</sup> These materials are not (yet) on the list of materials that the DOD recommends for reserves, however legislation is underway to address this issue. In 2010 Congress was considering legislative proposals that would qualify REEs as 'materials either strategic or critical to national security.'<sup>37</sup> If adopted, this qualification would allow the DOD to take actions to ensure supply and develop a domestic supply chain. It also marks the first step to incorporate REEs into the National Defense Stockpile. For the remainder of this case study, REEs will indeed be considered as strategic.

The above-mentioned legislation has a broader focus than the application of REEs in defense systems. Although the amounts used are often small, REEs are applied in many important sectors of the US economy ranging from health care, construction, utilities and transport. They also find many applications in the renewable energy industry. REEs are used in permanent magnets and rechargeable batteries for hybrid and electric vehicles, generators for wind turbines. Against the backdrop of climate change and calls for a transition to a greener economy, REEs are considered key to innovation and 'the growth of green jobs.'<sup>38</sup> Other usage of REEs includes automotive catalytic converters, fluid cracking catalysts in petroleum refining, and in consumer durables such as phosphors in colour television and flat panel displays such as those used in cell phones, portable DVD players, and laptops.<sup>39</sup>



## DOMESTIC PRODUCTION AND CONCERN REGARDING STRATEGIC MINERALS

Traditionally, the US has had a strong domestic mining industry. Up until 1973 it was the world's leading producer and exporter of minerals.<sup>40</sup> Figure 2 shows US mineral production in relation to global production in 2010. Over the past century, the US has become more import-dependent for its mineral supply. Whereas the US had an export-import balance between 1900 and 1929, this slowly shifted and by the 1970's import was three times larger than mineral exports.<sup>41</sup> Import has continued to grow, particularly for strategic minerals. Although the US also produces some alnico, ferrites and samarium cobalt domestically, it does not produce other strategic minerals such as neodymium-iron-boron.<sup>42</sup>

Mineral production of several strategic minerals is highlighted above. The US was once self-reliant on domestically produced REEs from the Mountain Pass mine in California. After the discovery of REEs deposits in 1949, the US performed all stages of REE processing between 1965 and 1985.<sup>43</sup> From the 1990s onward US REE manufacturing began to decline leading to the closure of Mountain Pass by Molycorp in 2002.<sup>44</sup> As a result, from that moment the US had no domestic mining or production capability for REEs, and the US has become almost 100% reliant on REE imports from China.<sup>45</sup>

Beryllium tells a different story. In 2000, the only US producer of beryllium, Brush Wellman, Inc. (BWI) closed its mining operations due to economic, health and safety issues.<sup>46</sup> BWI continued processing the mineral on the basis of supply from the national stockpile, but in order to avoid depletion the US had to look for foreign sources. The US started importing beryllium mainly from Kazakhstan. However, since Kazakh beryllium has insufficient purity to be used in critical defense applications, this turned out to be problematic. Furthermore, transferring technology to Kazakhstan in order to increase purity levels was considered a non-proliferation risk.<sup>47</sup>

Production Mineral	U.S.	World	U.S percent of World
(metric Tonnes)			
Beryllium	120	140	86%
Copper	1.190.000	15.800.000	8%
Diamonds	n/a	n/a	0%
Gold	210	2350	9%
Lead	400.000	3.900.000	10%
Magnesium (Compounds)	255.000	4.990.000	5%
Molybdenum	50.000	200.000	25%
Nickel	n/a	n/a	0%
Palladium	13	195	7%
Platinum	4	200	2%
Silver	1230	21.400	6%
Titanium ( mineral concentrates)	200.000	5.720.000	3%
Zinc	690.000	11.100.000	6%
Total selected Commodities	2.786.577	41.734.285	7%

FIGURE 5 US MINERAL PRODUCTION

SOURCE: USGS MINERAL COMMODITY SUMMARIES 2010

Aware of the supply risks that come with high import dependence, the US government took action to restart domestic production of beryllium. Due to its importance for US defense systems and its nuclear posture, the DOD has stepped into the market for high purity beryllium.<sup>48</sup> Using the authority granted by Title III of the Defense Production Act (50 U.S.C. App. 2061 et seq.), which allows expanding or restoring specific industrial capabilities for national defense, it provided loans to BWI in order to build and operate a new high purity beryllium production plant. As a result, the US is at the time of writing one of the most important producers of beryllium. With an annual production of 140 metric tonnes, it produces 86% of the global stock (see Figure 5).

US production of REEs has also picked up since 2007, when Molycorp Minerals resumed operations at Mountain Pass with the separation of bastnasite concentrates from stockpile produced before shutdown.<sup>49</sup> Molycorp Minerals it is projected to fully restart production again in 2012. The company argues for support: ‘With appropriate federal assistance for research, development and capital costs, Molycorp Minerals is prepared to move forward to re-establish domestic manufacturing capacity on an expedited basis.’<sup>50</sup> The company further plans to expand operations to the

production of metal, alloys and neodymium-iron-boron magnets. The expected production capacity upon restart is approximately 18,143 metric tonnes of rare earth oxide per year.<sup>51</sup> According to the USGS, the demand for REEs is expected to rise. This is partly due to projected growth of 10%-16% per year in the demand for permanent magnets and auto catalysts and an increase of 6%-8% per year of petroleum cracking catalysts.<sup>52</sup>

The decline of domestic production of strategic non-fuel minerals and growing import dependence were caused by increased consumption and decreased competitiveness of US minerals on the international market.<sup>53</sup> Various factors contributed to the decreased competitiveness of the US mining industry over the years, including limitations to access public lands, higher energy prices, and environmental, health and safety regulations.<sup>54</sup> Several strategic minerals either were not found in the US or could only be produced at costs far above existing market prices, promoting reliance on lower-cost foreign suppliers since 1951.<sup>55</sup> Rather than expand domestic production, the US increased its dependence on a few suppliers, notably those in developing countries.<sup>56</sup> As a consequence, US producers and manufacturers are now facing severe competition from the emerging economies, like China and India.<sup>57</sup> Due to strong competition from low cost producers, it similarly became difficult to develop viable domestic production capabilities without government support.

With growing import dependence, the issue of strategic non-fuel minerals has gained increased attention from US policy makers. In 2010 US Congress expressed concern about access to strategic minerals, particularly in the event when the US defense industry needs to respond to a national or international emergency.<sup>58</sup> In the preceding decade, however, no major new legislation has been adopted regarding strategic non-fuel minerals.

In 2010 however, in light of recent developments on the mineral market, the urgency among legislators to address America's mineral vulnerability has grown. This was the result of the possibility of economic disruptions and political tensions with primary suppliers.

Particularly, Chinese handling of its REEs monopoly has contributed to fears about the Chinese using exports of REEs as weapon of trade increasing anti-Chinese sentiment among US policy makers and

congressional leaders.<sup>59</sup> As a result of these developments, the debate in Congress on strategic non-fuel minerals has been revived and both the Senate and the House of Representatives have been considering new legislation on the matter. A description of these policy initiatives follows below, subsequent to an examination who the main actors are influencing US policy making on strategic non-fuel minerals.

### MAIN ACTORS

Besides Congress, the main governmental actors involved in the policy making process are the DOD, the Department of Energy (DOE) and to a lesser extent the Department of the Interior (DOI). At the time of writing, the Pentagon has not yet systematically assessed national security risks related to strategic non-fuel minerals. However, steps were taken to investigate the issue. Reports published by the Pentagon hint at the notion that strategic non-fuel minerals will continue to be essential to defense systems due to their life cycles and lack of substitutes, yet no department wide measures have been taken to alleviate the dependency on REEs. The DOD is in the early stages of assessing what steps can be taken to reduce its dependency on REEs and to expand sources of supply.<sup>60</sup> The DOE similarly believes that source of supply should be diversified and that investments should be made in domestic manufacturing and processing. Although green technologies rely heavily on REEs, the DOE does not consider supply restrictions of REE to be static, due to existing strategies to address the shortages. David Sandalow, Assistant Secretary for Policy and International Affairs of the DOE, stated that addressing the availability of REEs and other strategic materials requires a three-part approach, namely to globalize supply chains for strategic materials, to develop substitutes and to promote recycling, re-use and more efficient use of strategic materials.<sup>61</sup> Sandalow added there is no need to panic if these strategies are enacted wisely.

As the only major US REEs mining company, Molycorp plays a prominent role in promoting a domestic REE supply chain. Molycorp's stated long term objective is to re-establish a manufacturing capacity for intermediate magnet materials and finished neo magnets.<sup>62</sup> It argues that the responsible exploitation of domestic REEs reserves is the best way to ensure the magnet supply for defense purposes. US metal traders, by contrast, are less keen on current legislative proposals for the reestablishment of a domestic

supply chain. They do not see China's import restrictions as a direct threat. Instead, they fear that a domestic supply chain will put them out of business or decrease their profits.<sup>63</sup>

Think tanks in the field of international and national security have also picked up on the issue of strategic non-fuel minerals. Think tanks play an important role in shaping the debate by providing analysis and connecting US mineral producers, manufacturers, members of Congress and their staff, various branches of the US government, and other stakeholders. The most prominent contributions from think tanks to the debate include the Center for Strategic and International Studies (CSIS), the Center for a New American Century (CNAS), and the Institute for the Analysis of Global Security (IAGS). In May 2010 CSIS published a report entitled *'Rare Earth Elements: A Wrench in the Supply Chain?'* In this issue CSIS examines the supply and production, defense related issues and policy options related to REEs.<sup>64</sup> It concluded that *'[i]nsufficient attention has been paid to a broad range of important minerals that are scarce sources of renewable energy and whose continuing and increasing provision are essential for the functioning of industry and commerce throughout the developed world.'*<sup>65</sup> On 18 May 2010, CSIS hosted a roundtable session to discuss the challenges and opportunities the US and the broader transatlantic community are facing in ensuring reliable supply of strategic minerals. Participants included experts from the USGS and on US national security. They agreed that supply restriction of strategic non-fuel minerals would negatively affect US economic development and national security and that cooperation with the EU in this field was desirable. CNAS finds there is not enough awareness of US vulnerability to supply disruptions of strategic minerals.<sup>66</sup> Therefore, it has devoted one of its 'Natural Security Blogs' to minerals. In June 2009 CNAS published a working paper on the importance of strategic minerals and other natural resources for national security.<sup>67</sup> IAGS has gone a step further and set up a centre dedicated to the study of REEs. It founded the Technology and Rare Earth Metals (TREM) Center, whose mission is to *'create a forum where policymakers and companies from the minerals, defense technology, cleantech, automotive and finance sectors can advance policies that ensure secure and diverse supply chains for technology metals.'*<sup>68</sup>

The media has acted as a platform for Congressmen to raise public support for their legislative initiatives. Representative Mike Coffman (R-Colorado), for example, regularly appears in CNN interviews to comment on developments concerning REEs. Since the Sino-Japanese maritime incident in September 2010, media attention for strategic non-fuel minerals has increased dramatically. The reporting, before the G-20 summit in Seoul, South Korea, generally emphasized the negative effects and potential security threat of a Chinese monopoly on REEs and complained about short sightedness of US policy makers who let this happen. It feeds into a general anti-Chinese slant in US public opinion. Leading New York Times columnist Paul Krugman is illustrative of this strand. In an op-ed in October 2010 on rare earth metals he stated: 'I find this story [referring to the Chinese handling of the maritime incident] deeply disturbing, both for what it says about China and what it says about the US. On the one side, the affair highlights the fecklessness of US policy makers, who did nothing while an unreliable regime acquired a stranglehold on key materials. On the other side, the incident shows a Chinese government that is dangerously trigger-happy, willing to wage economic warfare on the slightest provocation.'<sup>69</sup> Krugman and other journalists support the development of a domestic supply chain for REEs and the diversification of supply with non-Chinese sources.

### CONTEMPORARY LEGISLATION

Strategic non-fuel minerals are addressed in several different policy documents, including the Defense Production Act, the National Defense Stock Piling Act, the Buy American Act, the 1941 Berry Amendment which requires the Pentagon to only procure domestically sourced specialty metals such as beryllium and titanium, and the Specialty Metal Provision.<sup>70</sup> Furthermore, legislation on other topics – such as national defense – may include measures related to strategic materials. Such was for instance the case with the National Defense Authorization acts 2010 and 2011. These documents do not provide a comprehensive framework for US mineral policy, differing in the definition and assessment of what strategic or critical non-fuel minerals are, however together they constitute a volume of policy resources. The most recent proposals regarding strategic minerals are independent bills.

**H.R. 4866 RESTART Act**

On 17 March 2010 Representative Coffman introduced the Rare Earths Supply-Chain Technology and Resources Transformation Act of 2010 (RESTART Act) intent on establishing a domestic supply cycle for REEs. According to the text, the goal of the RESTART Act is to 're-establish a competitive domestic rare earths minerals production industry, a domestic rare earth metal processing, refining, purification and metals production industry and a domestic rare earth metal based magnet production industry and supply chain in the United States.'<sup>71</sup> The bill proposes two instruments. On the one hand stockpiling REEs and on the other, providing government loans to re-establishing domestic mining and processing of REEs. The bill establishes mechanisms to report on and review international trade practices and to determine which of the REEs are critical to national and economic security. It tasks the DOD to start the procurement and stockpiling of REE, explicating that to this end REEs can be purchased from China to meet US national security and economic needs. The bill furthermore promotes the reestablishment of domestic mining plants and mechanisms for obtaining government loans to this end.

**S.3521 RESTART Act**

On 22 June 2010 the Rare Earths Supply Technology and Resources Transformation Act of 2010 was introduced by Senator Lisa Murkowski (R-Alaska). The goal of this bill is to 'establish a Rare Earth Policy Task Force to monitor and assist federal agencies in expediting the review and approval of permits to accelerate the completion of projects that will increase investment in, exploration for, and development of domestic rare earths.'<sup>72</sup> The bill acknowledges the urgent need to re-establish a domestic rare earth element supply chain since 'REEs form the backbone of both the defense and energy supply chain.' Therefore, this bill directs the Rare Earth Policy Task Force to report to Congress on the development of a domestic supply chain, on the REEs that are critical to clean energy technologies and national security, and on whether critical REEs should be stockpiled. In addition, the Task Force should guide the renewable energy industry in obtaining government loans. The bill furthermore directs the government to provide funds to academic institutions, federal laboratories, and private entities for innovation, training, and workforce development in the domestic REE supply chain. The bill has been referred to the committee of the Senate on Energy and Natural Resources.

**H.R. 6160 Rare Earths and Critical Materials Revitalization Act of 2010**

On 22 September 2010, immediately following the Chinese decision to restrict all REE exports to Japan as part of a Chinese-Japanese diplomatic incident involving a maritime collision, this legislative proposal was introduced by Representative Kathy Dahlkemper (D-Pennsylvania). The main goal of the Act is to 'develop a rare earth materials program, to amend the National Materials and Minerals Policy, Research and Development Act of 1980.'<sup>73</sup> This act would repeal the National Critical Materials Act of 1984 and focuses on the role of the Department of Energy. It calls for the establishment of a Research and Development Information Center within the DOE to collect information and report to Congress on REEs. This research program is also meant to support the development of new technologies with loan guarantees for commercial applications, and to encourage multidisciplinary collaboration between universities and with the European Commission.

**P.L. 111-84, the Fiscal Year 2010 National Defense Authorization Act**

As part of the annual defense authorization, this act requires the Pentagon to determine the extent of US mineral vulnerability. It calls for measures to determine which specific military weapons systems currently depend on REEs, how high the risks of restricted supply from foreign sources are, and what steps the DOD has taken to alleviate potential threats to national security.<sup>74</sup>

**H.R. 5136 Fiscal Year 2011 National Defense Authorization Act**

As part of the overall annual defense budget, this act requires the Secretary of Defense to make an assessment of the REE supply chain and determine which materials are strategic or critical to national security. The Act calls for a plan to ensure the long term availability of these materials by the end of 2015. The Act also explicitly directs the establishment of a domestic source of sintered neodymium-iron-boron magnets for defense systems.



## POLICY INSTRUMENTS

The US is also considering transforming the national defense stockpile into a Strategic Materials Security Program (SMSP). This transformation aims to improve US ability to adapt to developments on the strategic material market and to ensure availability of strategic non-fuel minerals for defense and economic purposes.<sup>75</sup> The proposal was put forward in the Reconfiguration of the National Defense Stockpile Report to Congress of April 2009 in response to congressional requests about the identification and availability of materials that are strategic or critical to defense interests. The report concluded that the DOD's current policy to dispose of stockpiled material requires revision. It recommends that the national defense stockpile be reconfigured to identify current and future US strategic material needs and threats, the ability to access these materials and appropriate mitigating strategies to ensure supply.<sup>76</sup> To this end, SMSP would monitor markets and enable planners to take advantage of global market conditions. Furthermore, it would establish supply chain commitments with producers and suppliers, monitor timely delivery of materials and store only a limited amount and types of materials. Compared to the national defense stockpile program, the SMSP would have a broader internal DOD profile and closer cooperation with other federal agencies. Aggregating material requirements of the DOD and other agencies would leverage the SMSP buying power and create greater opportunities to enter and exit markets and contribute to programmatic flexibility to efficiently and effectively acquire needed materials.<sup>77</sup> In sum, the SMSP has a broader focus than mere traditional stockpiling.

In August 2010 the Defense Logistics Agency of the Defense National Stockpile Centre published the SMSP Implementation Plan. This report to Congress gives an overview of the actors, responsibilities, legislation and funding required for the reconfiguration of the national defense stockpile as set out in the report of April 2010. For instance, the SMSP requires legislative changes to the Strategic and Critical Materials Stock Piling Act.<sup>78</sup>

Furthermore, the US filed a claim with the World Trade Organization (WTO) on 23 June 2009. In it the US cites measures that China allegedly uses to restrict exports of strategic non-fuel minerals and notes that there may be other restraints. The US has requested consultations with China on this issue, which was seconded by the EU, Canada, Mexico and Turkey.<sup>79</sup> In a

hearing in the House of Representatives on 16 March 2010 on ‘Rare Earth Minerals and 21st Century Industry’ international trade law expert Terence Stewart argued that the US should consider to file a second claim before the WTO against China because China is violating agreements regarding export taxes.<sup>80</sup>

## CONCLUSION

US strategic mineral policy appears to evolve in response to geopolitical tensions. This is historically consistent. The US holds a security-centric perspective of its mineral policy. What the US considers strategic materials varies according to defense needs and market developments such as supply, price and quality.

In short, the following elements are considered the driving factors of current US mineral policy on strategic and critical non-fuel minerals:

- Import dependency;
- (Lack of) Domestic production;
- Geopolitical tensions that impact reliability of foreign suppliers;
- Growing consumption, both domestic and global;
- Importance to the national economy of strategic non-fuel minerals using industries;
- Importance of strategic non-fuel minerals for defense systems;
- Anti-Chinese sentiment among opinion leaders and policy makers.

The US does not have an overarching strategic policy document on non-fuel minerals. Strategic non-fuel minerals are addressed in several different policy documents. They propose building domestic supply chains and stockpiling. Current legislative proposals concerning REEs are underway. This is the result of a heightened awareness on strategic non-fuel minerals. The main contributors to this debate are the DOD, the DOE, the DOI, REE mining company Molycorp, research institutes and the media.

In response to recent developments on mineral markets, different risk mitigating strategies are being used or under consideration, including:

- Legislative proposals to boost domestic production and stockpiling;
- Reducing dependency by diversification of supply and the development of new technologies;
- Transformation of the national defense stockpile into a broader strategic materials security program;
- Legal claims before the WTO about alleged Chinese export restrictions.

Events in History	Year	US Mineral Policy Related Events
WW I disrupts mineral US-European mineral trade	1914	
	1917	Domestic supplies of key commodities become insufficient: concept of strategic mineral resources is born
Start recovery from Great Depression	1933	Buy American Act: requires US government to buy domestically produced products, including raw materials
	1938	Strategic mineral investigations begin with funds from the Public Works Administration
Start of WW II		Raw material shortages threaten production of military equipment
	1939	Strategic Materials Act is passed and establishes National Defense Stockpile
	1946	Congress amends Strategic Materials Act, creating the Strategic and Critical Material Stockpiling Act, confirming Congress' commitment to supply security and giving the stockpile semi-permanent status
Start Korean War	1949	Discovery of REEs deposits in Mountain Pass, CA
	1950	Defense Production Act, authorizing the government to subsidize mineral production
	1965-1985	US performs all stages of REEs processing and is self-reliant on domestically produced REEs
Political unrests in southern Africa		US policy makers concerned with supply risks due to political unrest in southern Africa and communist expansion
	1970s-1980s	Aluminium, chrome, cobalt, manganese, nickel, PGMs and titanium are considered critical  US mineral imports are three times as high as exports

Oil crisis	1970	Mining and Minerals Policy Act, formally recognizing the importance of mining and domestic minerals production as US policy
	1973	US position as world leading producer and exporter of minerals starts to decline
	1976	National Commission on Supply Shortages warns about supply interruption risks related to unrests in African supplier states
Political insurrection in Zaire	1978	Temporary interruption of cobalt supply
	1979	Strategic and Critical Material Stockpiling Revision Act, updating the defense stockpile program and specifying the stockpile cannot be used to influence commodity prices
	1980	National Materials and Mineral Policy, Research and Development Act, concerning the improvement of materials information, analysis and policy coordination
	1984	Strategic and Critical Materials Act, establishes the National Critical Materials Council to promote Research and Development on critical materials
	1988	DOD becomes responsible for National Defense Stockpile
End of the Cold War	1990s	US REE production starts to decline
	1992	Last purchases of raw materials for National Defense Stockpile: rubber, tantalum
	1993	DOD starts partial sale of National Defense Stockpile
	2000	Brush Wellman, Inc. closes only US beryllium production facility
	2002	Molycorp closes Mountain Pass REE mine
	2006	Strategic Materials Protection Board is created (SMPB)
	2007	Some US REE production resumes: Molycorp starts separation of bastnasite concentrates from stockpile mined before shutdown

September 2010: China restricts REE exports following Sino-Japanese maritime incident

2008	<p>National Research Council develops methodology to evaluate the criticality of non-fuel minerals</p> <p>PGMs, REEs, indium, manganese, niobium are found critical</p>
2009	<p>23 February: SMPB: specialty metals are strategic but not critical to national security</p> <p>23 June: US files claim before WTO about Chinese export restrictions</p> <p>28 October: P.L. 111-84 Fiscal Year 2010 National Defense Authorization Act becomes public law, requiring the DOD to report on measures to alleviate national security threats from REE supply disruptions</p> <p>Proposal to reconfigure National Defense Stockpile into Strategic Materials Security Program</p>
2010	<p>17 March: introduction of H.R. 4866 Rare Earths Supply-Chain Technology and Resources Transformation (RESTART) Act proposes to re-establish a domestic REE supply cycle</p> <p>26 April: introduction of H.R. 5136 Fiscal Year 2011 National Defense Authorization Act, calling for measures to ensure long term availability of strategic and critical materials by 2015</p> <p>22 June: introduction of S.3521 Rare Earths Supply Technology and Resources Transformation (RESTART) Act</p> <p>22 September: introduction of H.R. 6160 Rare Earths and Critical Materials Revitalization Act, calling for the creation of a research program on REE within the DOE</p>
2012	<p>Planned restart of REE production from Mountain Pass</p>

## 2.3 THE UNITED KINGDOM

UK mineral policy primarily addresses strategic minerals from an economic point of view. It focuses its attention on those minerals that are considered essential to the most important sectors of the UK economy, including, the defense and security sectors. Its policies are based on the concept of 'material security' which addresses both supply and material risks, and leads the UK to promote domestic production capabilities as well as international free trade.

### BRIEF HISTORY

Concerns over strategic minerals in the UK go way back but gained policy prominence when the UK's position as a key producer of minerals started to decline. With decreased self-sufficiency, supply vulnerability has become a key issue at a time of economic or political turmoil. It has also stimulated domestic instances. For instance, during WWI and WWII shortages of supply resulted in the recycling of metals from non-critical applications to reduce import dependency, and to promote domestic production.<sup>81</sup> Current policy appears to follow this trend.

The concept of strategic minerals was introduced during the Cold War. Strategic minerals were defined by the British Geological Survey (BGS) as 'minerals and metals that were both critical to the manufacturing sector and vulnerable to interruptions in supply.'<sup>82</sup> This definition contains two important components. First, 'criticality', which describes minerals essential to the manufacturing sector and more broadly, the UK economy, also including minerals essential to defense systems. The second is 'vulnerability' and refers to minerals being increasingly imported from limited sources, making them vulnerable to supply disruptions.<sup>83</sup>

During the Cold War, the UK government proposed several measures to reduce this vulnerability, including diversifying sources of supply and maintaining stockpiles.<sup>84</sup> Stockpiles were particularly established for materials that were deemed essential for national defense, such as tungsten, used at that time in intercontinental ballistic missiles.<sup>85</sup> In the early 1980s, chromium, manganese and vanadium were considered 'strategic' because of their use in the steel industry and their restricted supply sources. The UK maintained stockpiles of these strategic minerals between 1983 and 1996.<sup>86</sup>

Besides stockpiling, another measure that was taken was to boost domestic production. In 1975 the UK established the Minerals Reconnaissance Program (MRP) to promote mineral exploration and development in the UK by way of attracting mining companies to the UK. The MRP also provided the government with information on minerals whose supplies could be threatened by political unrest.<sup>87</sup>

After the end of the Cold War, however, the concept of strategic minerals became unfashionable among UK policy makers. It was assumed that through globalization security of supply would no longer be an issue and the global market would allocate minerals to customers without significant risk or interruption caused by political factors.<sup>88</sup>

This optimism proved to be somewhat premature. New challenges such as climate change and the rapid economic growth of emerging economies like China and India raised the prospect of increased demand and competition for mineral resources. In contrast to the temporary spikes in demand surrounding historic events in the past, economic growth in Asia is seen as a long term structural change in the nature of the world economy. Increasing demand from, and mineral extraction in these emerging economies will continue.<sup>89</sup> In the UK it has led to a reassessment of its mineral policy.

#### UK DEFINITION OF STRATEGIC NON-FUEL MINERALS

BGS defines strategic minerals as materials ‘that are critical to certain industries; to parts of the national economy or to national defense capabilities, which would be seriously affected if they were not obtainable and at the same time are perceived to be vulnerable to interruptions of supply.’<sup>90</sup> These disruptions can be caused by political interference in the market, acts of sabotage, war, accidents, or industrial action. Key features of strategic minerals are a lack of adequate substitutes and a dependence on a limited number of producers with limited capacity to increase production quickly.

Although this definition acknowledges the importance of strategic minerals for defense capabilities, UK policy documents and research on minerals focus mainly on those minerals that are essential to the British economy. This means that for the UK, strategic non-fuel minerals not only comprise materials that are primarily used in high-technology and defense

applications, such as REEs, but also industrial and construction minerals. Policy documents focus on the key economic sectors, including defense, that have legitimate concerns over long term material (and mineral) availability.<sup>91</sup>

Long term availability is associated with ‘material security’, a recurrent term in UK mineral policy documents. Despite the lack of an official definition, material security is understood to mean a situation in which ‘there is no significant disadvantage to the national economy or national defense caused by restricted access to specific materials.’<sup>92</sup> Material security is determined by both material and supply risks. Restricted access, such as imposed export tariffs, quotas, or restrictions, can make a mineral prohibitively expensive or negate access to the material altogether. Such policy can be informed by political and economic motivations of the mineral supplier. The situation becomes critical when a specific material is also difficult to substitute, increasing material insecurity. In March 2008, the Resource Efficiency Knowledge Transfer Network produced a strategic report with support from the Department of Business, Enterprise and Regulatory Reform (BERR). Figure 6 shows the report’s systematic inventory of factors influencing both types of risks.

	Material Risk	Supply Risk
Primary Importance Secondary Importance	Lack of Substitutability	Supply Monopoly
	Application Critical to Enabling Security or Economic Growth	Political Instability in Major Supplying Region/Country
	Associated Environmental Impact	Major Supplying Region/Country Vulnerable to the Effects of Climate Change
	Global Consumption Levels	Geopolitical – Privileged Supply to Own or Other Countries
	Global Warming Potential from Extraction and Production Process	Dependence on Virgin Resources (lack of recycling)
	Total Material Requirement for Extraction and Production Process	Potential to Displace Virgin Material by Resource Efficiency Strategies
	Price	Scarcity, Reserves or Reserve Base

FIGURE 6 DETERMINANTS OF MATERIAL SECURITY<sup>93</sup>



Strategic minerals are those minerals that are essential to the most important sectors of the UK economy. They include energy minerals, construction minerals, and minerals that support industries with a high added value component, such as chemical feed stocks, and finally, materials that run a material risk as defined above.<sup>94</sup> For an overview see figure 7.

Industrial Minerals	Construction Minerals	Material Risk Materials
Kaolin	Aggregates	Zirconium
Ball clay	Brick clay	Indium
Limestone	Cement making materials	Lithium
Silica sand	Gypsum	Potash
Potash	Sand	Molybdenum
Salt	Gravel	Borate
Fluorspar barites	Slate	Iron
Sulphur		Feldspar
Bentonite		
Magnesia		

FIGURE 7 UK STRATEGIC MINERALS<sup>95, 96</sup>

The UK was a leading world producer of several minerals until the mid 19th century, including iron, tin, copper and lead.<sup>97</sup> Due to high extraction costs and competition from growth in lower-cost production overseas, domestic production has declined. Nonetheless, the UK remains an important producer of a wide range of minerals. It produces most of the above-mentioned construction minerals domestically, and a fair share of the industrial minerals. In 2008, the UK produced 218.5 million metric tonnes of construction minerals and 23.3 million metric tonnes of industrial minerals, accounting for 83.7% and 8.8% of total national mineral production respectively.<sup>98</sup> This is however not sufficient to meet demand. Despite important production capacity, the UK is not self-sufficient. For most industrial and construction minerals, except for lead and aluminium, which is covered by recycling from old scrap, the UK is increasingly import-dependent.<sup>99</sup> Of the material risk materials, the UK only produces potash domestically. In 2008 the UK imported minerals with a total value of £ 5498.4 million. It also imported some 2500 metric tonnes of rare earth elements.

### UK POLICY MAKERS AND STRATEGIC NON-FUEL MINERALS

Access to strategic non-fuel minerals does not appear to be considered a major challenge. Supply restrictions of these materials are for instance considered a lesser threat to national security than climate change or energy insecurity.<sup>100</sup> This can be explained by the large domestic source of supply for the majority of industrial and construction minerals and British support for global market mechanisms.

The UK has an interest in a healthy domestic mining sector. After all, the mining industry is an important contributor to the overall economy, providing necessary materials in downstream industries and providing jobs. With about 2000 mines in the UK and 1000 companies operating them, some 55.000 people are employed directly in the extractive mining industries and around 1.9 million people are employed indirectly.<sup>101</sup> The UK also exports minerals, in which it has focused primarily on protecting its domestic production capacity. Nonetheless, concerns are rising that this may not be sufficient. National industries have been burdened by rising global mineral prices and with limited room for improving domestic production efficiency and few opportunities for substitution of the most expensive materials, economic pressure is expected to rise.<sup>102</sup> As a consequence, UK policy makers are openly questioning whether ensuring material security may need a more strategic approach than ‘the invisible hand of the market.’<sup>103</sup>

An indication of the higher awareness of the issue among UK policy makers is that different government institutions have commissioned reports on current developments in the mineral market and on UK imports of REEs in particular. For example, in May 2010 the Department for Transport and the Department for Business, Enterprise and Regulatory Reform (BERR) tasked the think tank Oakdene Hollins to investigate rare earth resources, their supply constraints and in which important industries they are used.<sup>104</sup> The Government Office of Science also published a report that same month entitled Science and Engineering Assurance Review of the Department for Transport, in which rare earth metals are mentioned as an important contributor to the reduction of carbon dioxide emissions.<sup>105</sup>

Heightened attention for the issue of non-fuel strategic minerals derives from various economic and political factors. Primarily, developments in the

global mineral market have a direct impact on the UK domestic mining sector. The UK increasingly faces competition from emerging economies, such as China. These emerging economies compete with the UK both with respect to demand and supply. For their economic development emerging economies increasingly need minerals. This increases strain on existing supplies, particularly when it comes to less common metals. Concurrent with their economic development, emerging economies are often resource-rich. Increasing their mineral production capability places them in direct competition with the UK's minerals industry. These states often produce at lower costs and with limited regard for environmental regulation.

### UK MINERAL POLICY DOCUMENTS

According to the UK Minerals Forum, a leading industry-sponsored agency (on which more below), the UK does not have a comprehensive strategy on minerals.<sup>106</sup> Instead, the UK government and its subordinate administrations (in Wales, Scotland and Northern Ireland) all have their own specific mineral policies. These policies vary in scope and focus: some focus on minerals in general; others on specific ones. They include policies on mineral extraction, waste management, prevention of land and environmental degradation, and sustainable development of the mining industry.<sup>107</sup> Taken together, these documents constitute the body of UK mineral policy whose overall objective is 'to secure adequate and steady supplies of minerals needed by society and the economy within the limits set by the environment, assessed through sustainability appraisal, without irreversible damage.'<sup>108</sup> The UK sees the continuation and safeguarding of domestic production as an important way to meet domestic demand and to secure its long term supply of strategic non-fuel minerals. To help ensure supply for the future, the policies focus on the identification of indigenous mineral resources.<sup>109</sup> They also aim to keep the domestic industry competitive on a global market. On the other hand, they attempt to prevent land degradation, environmental degradation and minimize waste resulting from intensive mining.<sup>110</sup>

### UK GOVERNMENT POLICY

The national mineral policy for the UK is set out in two main documents: Minerals and Planning Statements 1: Planning and Mineral (MPS1) and Minerals Policy Statement 2: Controlling and Mitigating the Environmental Effects of Minerals Extraction in England (MPS2). It is made explicit that

these documents ‘complement, but do not replace or overrule, other national planning policies, and should be read in conjunction with other relevant statements of national policies.’<sup>111</sup>

The main subject of MPS1 and MPS2 are minerals. The documents are not part of a broader strategy, such as the Strategic Defense Review (see below). This is likely a consequence of the UK’s broad definition of strategic minerals which encompasses a large number of industrial and construction minerals. MPS1 contains the government’s overarching planning policies and principles.<sup>112</sup> Its objective is to maximize the benefits and minimize the negative effects of domestic mineral activity. It aims to ensure that sufficient land is available for the extraction of those minerals that are important to the economy, while satisfying a range of other concerns regarding environmental protection and sustainable development.<sup>113</sup> To source mineral supplies domestically, MPS1 proposes means to identify minerals that are of national and regional importance, to undertake regular assessments of the reserves, and to define mineral safeguarding areas in order to prevent resources from being needlessly sterilized by non-mineral development. MPS2 iterates that the exploitation of the UK’s mineral resources contributes to national prosperity and well being and that the ‘supply of essential materials for the construction, energy supply, manufacturing and other industries enables social and economic progress.’<sup>114</sup> The main focus of MPS2 is on the minimization of the environmental effects of domestic mineral extraction.

Strategic minerals are also discussed in other policy documents. In ‘A Strong Britain in an Age of Uncertainty: The National Security Strategy’ REEs are considered a key component of low-carbon and military technologies. It acknowledges that export restrictions on REEs may weaken strategic industrial sectors of the UK and increase global competition and the prospect of conflicts over access.<sup>115</sup> The UK Ministry of Defense’s strategy review is the most recent document that mentions REEs. ‘Securing Britain in an Age of Insecurity: The Strategic Defense and Security Review’ was presented to the UK parliament on 10 October 2010. It builds on the priorities identified in the National Security Strategy and details the transformation of the armed forces in light of emerging threats. REEs are mentioned in relation to the objective of ensuring sure that the UK has a coherent defense capability in 2020. It reiterates the point expressed in the National Security Strategy that REEs are key minerals for strategic UK

industries and crucial for low-carbon technologies aimed at mitigating climate change. Access to REEs and other resources is considered at risk due to competition for resources among other countries. Such competition, which may result in conflict or increased migratory pressures, is considered to be detrimental to the UK's national security.<sup>116</sup> But constraints in accessing specific materials will also negatively affect 'the security impacts of climate change, which may exacerbate existing security threats.'<sup>117</sup> REEs are therefore important both in the military sense and in the broader (economic, environmental) sense of UK national security. Overall, however, no policy options are presented, beyond signalling the importance of REEs.

### **Main Actors**

The current debate in the UK on strategic non-fuel minerals is shaped by various governmental actors, the mining industry and the media.

### **Government**

The main governmental actors are the UK government, which formulates overarching policies, and local authorities, who implement national policies and advise the UK and devolving governments on different local and technical aspects of mineral extraction in their region.<sup>118</sup> The Department of Communities and Local Government (DCLG) is charged with planning mineral policy. Also involved are the Department for Environment, Food and Rural Affairs (DEFRA), which sets out the environmental policy, the Department for Work and Pensions (DWP), which administers statutory control over mine and monitors safety, and the Department of Trade and Industry (DTI), which acts as a sponsor for all mineral sectors.

### **Minerals Industry**

The UK has a large number of companies operating in its mineral industry. For instance Tarmac Ltd. is the biggest UK producer of aggregates Silbelco UK. A leading UK producer of ball clay and barytes output is dominated by M-I Drilling Fluids UK.<sup>119</sup> Other companies include British Alcan Aluminium Ltd. (aluminium), Glebe Mines Ltd. (fluorspar), Johnson Matthey plc (platinum group metals) Cleveland Potash Ltd (potash), and Corus Group (steel). Anglesey Aluminium is one of the mining companies that operate under Rio Tinto, a leading international mining group headquartered in the UK. BHP Billiton, another world leading mineral resources producer, also has several offices in the UK. Besides numerous mining and quarrying

companies, a significant segment of the UK mineral industry is formed by a few manufacturing industries including companies that produce automotive and aviation products, and machine tools.<sup>120</sup> The UK's mineral industry has voiced concerns about recent developments on the mineral market and the way the government has responded to these.

A significant proportion of minerals, aside from material risk metals, still come from UK mines. However, Less Common Metals, a small-scale British manufacturer of rare earth metals, states that REE manufacturers are currently dependent on just one source, China, and non-Chinese sources are needed to meet increasing demand.<sup>121</sup> To secure supply of non-Chinese sources, the industry argues that the government should maximize the use of the UK's domestic resources.<sup>122</sup>

The industry simultaneously points out, however, that it is difficult to develop these domestic sources. Firstly, the industry is facing increased difficulties in exploiting new extraction sites, due to environmental legislation. Secondly, it believes that the UK lacks a coherent overarching and forward looking national policy that effectively overviews needs of the UK mineral industry. The Confederation of British Industry's (CBI, on which more below) Minerals Group, for instance, insists that a strategic view of the future development of all UK mineral resources is needed together with a better informed debate.<sup>123</sup> Thirdly, the industry complains about a growing volume of mineral legislation, particularly 'rules that are not properly thought through and are often devised and applied without proper 'joined-up thinking' on the part of diverse regulators.'<sup>124</sup>

Often, these rules emanate from European Union (EU) institutions in Brussels and are incorporated in national legislation. The industry believes this adds to overall cost increases, complexity, and bureaucracy of UK mineral policy. As a first step, the industry believes the UK should improve its knowledge base on strategic (material risk) minerals and value its domestic sources as national assets. In order to do so, the UK's demand from domestic and foreign sources should be kept under regular review and the location, supply, and other characteristics of strategic minerals should be monitored.

The industry also argues for an improved interface with the government. Currently, CBI, a leading UK business lobbying organization, is representing

the interests of over 500 companies involved in the mineral industry. It aims to be the voice for the sector as a whole. CBI endeavors to influence UK and EU legislation and regulation that affect the mineral industry. CBI is also a sponsor member of the Associate Parliamentary Minerals Group, whose purpose is 'to promote parliamentary awareness of the importance of minerals, provide information on developments in mineral usage, policy and regulation, and act as an information exchange between parliamentarians and the industry.'<sup>125</sup> The group formulates policy briefs and parliamentary briefs in which it offers insights and recommendations on important mineral policy areas.

In 2006, CBI set up the UK Mineral Forum, which plays an important role in bringing together stakeholders from the government, industry, and society. The Forum focuses on mineral supply security, the development of, and demand for indigenous minerals and sustainable development. It also assesses the effects of national and international legislative proposals for mineral supply. By hosting regular meetings and working groups and by publishing reports, the Mineral Forum contributes to information exchange and heightened awareness of strategic minerals.<sup>126</sup>

### **Think Tanks**

At the time of writing, the UK's most influential think tanks have not contributed much to the debate on strategic minerals. One exception is the publication 'Sustainable Energy Security: Strategic Risks and Opportunities for Business 2010' by Chatham House. The report mentions REEs in light of its discussion of green energy as a means of energy security. It states that REEs are essential to wind turbines and that supply restraints may pose a threat to energy security. It recommends to re-use and recycle minerals or to develop substitutes.<sup>127</sup>

### **Media**

Since a few years, the UK media has occasionally reported on the issue of strategic minerals. The media reports that minerals will become an increasingly important commodity. In January 2010, 'The Independent' labelled minerals as 'the commodity that has become the new oil' and the newspaper 'The Times' stated that minerals will be the source of political power in the 21st century.<sup>128</sup> Reporting is linked to the heightened attention paid to climate change. In this context, the Independent called REEs the

‘precious metals that could save the planet’ and the driving force behind a revolution in low-carbon technology.<sup>129</sup> Supply disruptions are considered a threat to the transition to a greener economy. The Times Asia Business Correspondent Leo Lewis reiterates that securing the supply of minerals is essential for high-technology and green energy industries, but that it does not end there. He illustrates that also the supply of potash for crop fertilizer ‘may become increasingly tormented by trade restrictions and politicized resource control.’<sup>130</sup> This is particularly relevant for the UK, which is a large producer of potash and potash products.

The media reporting on minerals, focus on the role of China. Particularly after the Sino-Japanese maritime incident in September 2010, reporting on China’s monopoly on REEs spiked.

Times journalist David Robertson already reported about upcoming resource nationalism, in an article in February 2008 on Chinese business deals with foreign mineral suppliers to secure supply for its rapidly growing domestic consumption.<sup>131</sup> In August 2009, ‘Times journalist’ Leo Lewis reported on Japanese concerns about a Chinese embargo on rare earth metals. No reference was made to possible implications for the UK.<sup>132</sup>

When cited, manufacturers use diplomatic and cautious language to express their unease with China’s dominant market position and its ability to cause a supply disruption. In order to avoid mineral business deals with the Chinese from getting affected, suggestions from the industry that China uses to control its position and to exercise political influence are avoided. The mineral industry is not so much concerned about the Chinese using trade as a tool of muscular foreign policy. Instead, they fear that a few years down the road, the Chinese will not need or want to explore Western business opportunities any more.<sup>133</sup>

Besides focusing on China’s role, the media also provides a platform for experts to voice their concerns about perceived complacency of the West. For example, The Times quoted Jack Lifton, an authority on rare earth minerals, as saying that ‘[w]e are at economic war’ and that ‘the West has been sound asleep on this. The level of ignorance about the upstream of mineral supply... is just out of this world.’<sup>134</sup> By using such language the British media contributes to building a sense of urgency among the general public to address the issue.



## CONCLUSION

The UK emphasizes the economic and industrial dimension in its debate on material security. Strategic minerals for the UK are those minerals that are essential to its economy, and therefore include energy minerals, construction minerals and minerals that support industries with a high added-value component. Material risk minerals are but one subgroup of this. Access to high-technology metals, including REEs, present a defense interest and have been labelled as such in the latest national security strategy, absent policy initiatives. Even though the UK has a sizeable defense industry, the defense component is considered of secondary importance. REEs are also considered key for low-carbon energy technologies important in mitigating climate change and improving energy security. Energy security is considered a more important challenge than securing supply of strategic materials.

The UK does not have a comprehensive strategy on minerals. The UK government and the devolved administrations have their own mineral policies, which focus mainly on planning and on mitigating environmental effects of mineral activities. Overall the objective of the different policies is:

- to continue and safeguard mineral supplies needed by society and the economy;
- to value domestic sources as national assets;
- to develop domestic sourcing;
- to maintain a competitive domestic mineral industry;
- to exploit domestic minerals in a sustainable manner, respecting the environment and society.

Securing indigenous supply is a historically consistent policy instrument of the UK in response to material scarcity. Maintaining a competitive domestic mining industry is important to the UK for economic and political reasons. Not surprising, the mineral industry is an important actor in the policy debate.

In general, minerals receive a lot of attention from UK policy makers. As the belief that the market will allocate the required resources is still dominant, concerns about access to materials needed for high technologies are not significantly high. Recent policy documents, however, indicate that the UK is moving towards a reassessment of this thinking. As a consequence, UK mineral policy may gain a more strategic and national security outlook in the coming years.

Events in History	Year	UK Mineral Policy Related Events
WW I	1914-1918	Supply shortages result in recycling of metals to reduce import dependency
WWII	1940-1945	Supply shortages result in recycling of metals to reduce import dependency
	1970s	UK government introduces system of supply and demand planning guidelines: promotes long term planning, reduces uncertainty and encourages investments
	1975	MRP: promoted mineral exploration and development by attracting mineral companies to the UK
Unrests in southern Africa	1980s	Heightened supply risks for chromium, manganese and vanadium
	1983	Cold War leads to creation of strategic metal stockpiles, for example of tungsten, chromium, manganese and vanadium
End of the Cold War	1990s	Concept of strategic minerals becomes unfashionable due to optimism over globalization and belief in the market as optimum allocation mechanism for minerals
	1996	Abolishment of strategic mineral stockpile
	2005	23 May: MPS 2: Controlling and Mitigating the Environmental Effects of Mineral Extraction in England 13 November: MPS 1: Planning and Minerals, aimed at maximizing benefits and minimizing negative effects of domestic mineral activity
	2006	Establishment of UK Mineral Forum by CBI, with the purpose of drawing together all key stakeholders to promote sustainable management and supply of UK minerals
	2008	Rare metals start to gain media attention
	2009	CBI publishes report 'Shaping UK Minerals Policy'

September 2010: China restricts REE exports following Sino-Japanese maritime incident

2010

May: Department for Transport and BERR order report on REE supply risks and impact

8 June: Chatham House publishes report on Sustainable Energy Security mentioning REEs

September - October: heightened media attention for REE after Chinese export restrictions

18 October: National Security Strategy: A Strong Britain in an Age of Uncertainty, which considers REE as key component of low-carbon and military technologies

19 October: Securing Britain in an Age of Insecurity: The Strategic Defense and Security Review, reiterates importance of REE for UK defense capabilities and energy technologies aimed at improving energy security and mitigating climate change

## 2.4 JAPAN

Japan's mineral policy is deliberate and purpose-driven. It is based on four central pillars with the objective of sustaining its economic security: diversifying supply by developing alternative sources of minerals in resource-rich regions or in the Japanese seabed while maintaining good relations with its neighbours; recycling domestic minerals in an approach known as 'urban mining'; developing alternative materials through R&D efforts in innovation; and stockpiling strategic materials.

### BRIEF HISTORY

A historically persistent issue of concern for Japanese policymakers is the need to secure mineral supplies for its high-tech manufacturing industries. In the 20th century during the run-up to WWII Japan faced a massive interruption in its supplies of steel, oil and rubber. This threatened Japan's military production capability and it motivated the Japanese government to develop an approach to mineral scarcity based on three instruments that exist to this day. It led to the creation of a stockpile of critical materials for civilian and military applications, to encourage domestic industries, to develop alternative sources and to recycle strategic non-fuel minerals.<sup>135</sup> As the situation became more pressing, this mineral insecurity contributed to Emperor Hirohito and Prime Minister Hideki Tojo's decision to use military force against the United States in 1941.

In 1963 the Ministry of Economy, Trade and Industry (METI) established the Metal Mining Agency of Japan (MMAJ) and tasked it to ensure a stable supply of non-ferrous metal and mineral resources. The MMAJ is the main organization that executes the government's mineral policies.<sup>136</sup> In the 1970s the oil crises heightened awareness of Japan's vulnerability as an importer of energy resources and non-fuel minerals. It underscored the negative impact of supply disruptions on the Japanese economy.<sup>137</sup>

Strategic non-fuel minerals have consistently been an issue of concern because of the continuous risk of supply constraints and their detrimental impact on Japan's industries.<sup>138</sup> These concerns stem from its import dependency, making it vulnerable to supply disruptions. For instance, Japan is 100% reliable on imports for rare earth elements.<sup>139</sup> Complicating the mineral issue further, Japan's imported minerals come from few foreign sources. In 2005, 44% of Japan's nickel import came from Indonesia and

49 % of chromium import from South Africa.<sup>140</sup> However 90% of Japan's REEs come from China. In 2008 the centrality of the challenge to secure mineral supplies resurfaced, triggered by the global economic recession, as well as in 2010 again, as a diplomatic incident between Japan and China triggered a temporary stop in rare earth element exports to Japan.

### JAPAN'S DEFINITION OF STRATEGIC NON-FUEL MINERALS

There is no single definition of strategic non-fuel minerals in Japanese policy. Most policy documents refer to 'rare metals', however instead of reflecting the group of 17 rare earth elements, this appears as the Japanese variant of 'strategic non-fuel minerals.' From an evaluation of the policy documents it can be concluded that – comparable to the other case studies – the concept of 'rare metals' has two qualifiers. The first is that these minerals are used in industries or products essential to the Japanese economy. The second is their criticality given the risk of, and/or negative effects associated with supply disruption. Rare metals are considered metal resources that are vital to Japan's economic and industrial activities and whose supply disruption would have a great effect on its economy.<sup>141</sup>

METI states that: 'Rare metals are indispensable for the manufacturing of automobiles and IT products, etc. Therefore, it is extremely important to ensure stable supplies of such metals from the standpoint of maintaining and strengthening the competitiveness of Japan's manufacturing industry.'<sup>142</sup> Another government agency, the Japan Oil, Gas and Metal National Corporation (JOGMEC), describes rare metals as 'a resource critical to the modern economy' and 'essential to modern life and industry.' JOGMEC compares rare metals with energy resources by saying that they are 'as crucial to the modern economy as petroleum and LPG (Liquefied Petroleum Gas).'<sup>143</sup> In the remainder of this case study 'rare metals' and strategic non-fuel minerals will be used interchangeably.

### JAPAN'S STRATEGIC MINERALS

Japan considers various metal resources, including REE, as strategic. Japan is the largest importer of REEs from China serving critical industries such as Japan's high-tech sector and the hybrid-electricity automobile industry.<sup>144</sup> Seven types of non-fuel minerals are stockpiled by JOGMEC: nickel, chromium, tungsten, cobalt, molybdenum, manganese and vanadium. Access to the following minerals is closely monitored by JOGMEC, though

they are not stockpiled. These are indium, REEs, platinum, gallium, niobium, tantalum and strontium.<sup>145</sup> On October 2, 2010 Japan announced a study to consider adding REEs to the national stockpile.<sup>146</sup> These two lists offer the clearest indication of Japan's strategic non-fuel minerals.

Japan is a resource-poor country with an expansive high-tech industry, leaving it dependent on foreign suppliers. Its mining industry is dominated by metals and metal products. This also means that copper and iron remain important base metals for Japan's industries.<sup>147</sup> In addition, Japan has an extensive mineral processing industry. Its main domestic production capacity consists of base metals from ore concentrates, such as copper, lead, zinc and nickel. Production of two of these currently exceeds domestic demand. In 2009 Japan produced an excess of 550,000 tonnes of copper and 106000 tonnes of zinc, most of which was exported to China.<sup>148</sup> While it was formerly a world leading producer of indium, as of 2010 Japan has next to no remaining domestic production capacity.

Due to its high-tech manufacturing industries, Japan is a world leading consumer of strategic non-fuel minerals. Japan is a top 5 global consumer of eight of these minerals, figuring alongside China and the US.<sup>149</sup> These eight metals are: nickel, tungsten, cobalt, molybdenum, manganese, vanadium, indium and REEs. In addition, the main strategic non-fuel minerals that Japan consumes are nickel, chromium, tungsten, cobalt, molybdenum, manganese, vanadium, dysprosium and indium. Regarding the latter, Japan consumes 60% of world supply of indium. It is used for the manufacturing of electronic devices including transparent electrodes used in Liquid Crystal Displays (LCD) and solar batteries.<sup>150</sup> The demand for indium is expected to increase due to the growing demand for plasma screen television. Japan is also the biggest global consumer of dysprosium, which is used in the production of information communication technologies, mobile phones and hybrid cars.<sup>151</sup>

### CONCERNS OVER STRATEGIC MINERAL RESOURCES

Heightened attention to strategic non-fuel minerals derives from the importance of these materials for Japanese business and concerns over supply disruption. Accounting for approximately 20% of Gross Domestic Product (GDP) and 90% of R&D investment of the private sector, manufacturing is the main driving force of Japan's economic growth.<sup>152</sup>

Japan is also a world leading exporter of such products to the US, Europe and other Asian countries, making export another important pillar of the Japanese economy.<sup>153</sup> Japan uses rare metals to manufacture consumer products including white goods, cars, computers and cell phones. Particularly the automobile industry has invested heavily in developing hybrid and electric cars and is among the largest consumers of rare earth elements.<sup>154</sup>

A further complicating element is that the Japanese government is seeking to strengthen the country's position in new industries that similarly require rare metals such as the robotics industry and aerospace. These industries are also expected to become a leading sector of Japanese manufacturing.<sup>155</sup> Thirdly, aware of the impact of its manufacturing activities on the environment, Japan is promoting the use of green technology, for example in fuel-efficient, low-emission, environmentally-friendly compact automobiles and aircrafts.

In general, supply risks have increased due to growing demand from emerging economies. Concurrently, Japan's influence as a leading consumer is decreasing since the rare metals market is becoming a seller's market.<sup>156</sup> On the other hand, mineral producing states are increasingly showing signs of resource nationalism, using their mineral production primarily to meet their own domestic demands and restricting foreign access to their resources. Tokyo notes with concern a changing business climate whereby 'Japanese companies trying to acquire mining areas for exploration or development in such countries are facing the growing need to negotiate with the government or state-run companies.'<sup>157</sup>

Due to its high import dependency on China, Japan is particularly worried about Chinese protectionist policies. Japanese companies became concerned about supply shortages in rare earth elements from China in July 2010, when Beijing cut its export quota to bolster prices and meet domestic demand. In September 2010, Japanese companies reported that China had halted exports of REEs to Japan. The restrictions followed the arrest of a Chinese fishing boat captain involved in a collision with the Japanese Coast Guard near the Senkaku Islands.

The supply restrictions did not directly affect Japanese companies to the extent that they had to shut down or suspend production because of remaining stocks of REEs.<sup>158</sup> However, it was estimated that if the interruption of Chinese REE exports had continued, Japan could have faced a shortage of about 10,000 tonnes in spite of additional shipments from other sources beyond China.<sup>159</sup> This caused disquiet among the Japanese business community, which expressed its concerns to the Japanese government. In response, METI Minister Akihiro Ohata stated he would try to allocate the 'necessary funds' to help businesses affected by the situation.<sup>160</sup> In general, the Japanese government tried to convince the Chinese government through diplomatic channels to resume exports to Japan, in order to prevent damage to its economy. The response from the Japanese government indicated that securing reliable supply had become both a political and economic priority to Japanese policy makers. Foreign Minister Saeji Maehara foreshadowed that he believed it to be 'quite a healthy development for each country to start resource diplomacy after developing a sense of crisis because of the latest incident.'<sup>161</sup>

### JAPANESE POLICY DOCUMENTS

Due to its concerns about supply shortages of strategic non-fuel minerals Japan has developed a comprehensive strategy set out in two main policy documents: the 'Strategy for Ensuring Stable Supplies of Rare Metals' of July 2009 and the 100 Actions to Launch Japan's New Growth Industry of August 2010. These are detailed below.

#### **Strategy for Ensuring Stable Supplies of Rare Metals**

In 2008 the Japanese government expressed its intent to develop 'a comprehensive strategy to secure stable supplies of rare metals including recycling of scraps as well as ensuring resources.'<sup>162</sup> In July 2009 this resulted in the 'Strategy for Ensuring Stable Supplies of Rare Metals'. Although this strategy complements previous existing strategies on economic growth, it can be considered a stand-alone policy document since it focuses exclusively on rare metals. The overall objective of the strategy is to ensure stable supplies of rare metals and to determine the criticality of different rare metals. The strategy declares that the 'evaluation of the supply situation is the most important factor in the determination of the relative priority' of strategic non-fuel mineral resources.<sup>163</sup> It urges the



government to adopt a focused, strategic approach to realize a stable supply of rare metals. The strategy has four elements:

- securing overseas resources;
- recycling;
- developing alternative materials;
- and stockpiling.

The first Japanese policy objective is to avoid dependence on monopolistic producers. To secure overseas resources the strategy calls for ‘increased Japanese support for mining development in foreign countries and infrastructure development in the surrounding areas by extending official development assistance (ODA).’<sup>164</sup> To this end, the government should actively use the functions of JOGMEC and seek cooperation in fields of technology transfer and environmental conservation. Japan has been engaged in development cooperation with states in Central Asia, South America and Africa in order to develop new sources. In October 2010, the Japanese government signed a Memorandum of Understanding (MOU) with the Mongolian government to develop a rare earths project as well as lithium and gallium ventures. Similar MOUs related to mineral resources have been signed with Kazakhstan, Uzbekistan, Mozambique, Bolivia and Namibia.

These development cooperation agreements are essentially based on supporting the country’s mining activities and are part of Japan’s overall resource diplomacy. Japanese policy calls for a ‘seamless system for contributing to developing countries’, providing technical expertise and financial assistance at all stages of mineral resource exploration, development and operation. This includes strengthening diplomatic ties, providing technical assistance, facilitating infrastructure development, stimulating industrial cooperation and offering financial support and loans through agencies such as the Japan Bank for International Cooperation (JBIC, on which more below), the Japan International Cooperation Agency (JICA) and the Nippon Export and Investment Insurance (NEXI).

The strategy also calls for the establishment of a recycling system of scrap from products that contain high content of rare metals (such as cell phones and digital cameras). The strategy promotes a better use of the existing recycling system and the creation of a recycling-oriented Japanese society.

Recycling has been a core element of Japanese mineral policy since 1998 when the Law for Recycling of Specified Kinds of Home Appliances was passed. Policies of recycling started in response to concern over climate change and the pending Kyoto Protocol in the late 1990's, emphasizing air-conditionings and other home appliances. The approach has slowly been enlarged to include automobiles, cell-phones and digital cameras. In addition, recycling is also more and more considered an element of foreign policy as other Asian countries are being engaged in developing regional recycling initiatives.

To promote research and development of alternative materials, the strategy calls for partnerships between upstream and downstream industries, cross-industry actors and between government industry and academia.

Finally, in order to dampen the effects of supply risks, Japan holds a national stockpile equivalent to 42 days of standard consumption in Japan.<sup>165</sup> The materials included in the stockpile have been mentioned above. The strategy calls for better use of the rare metals stockpile through a continuous evaluation of supply and demand trends in the market and on the needs of the industry.

### **100 Actions to Launch Japan's New Growth Industry**

The 100 Actions Plan of August 2010 presents the key policies of METI for the fiscal year 2011. It contains 100 specific actions that METI will implement to realize the various objectives mentioned in the Industrial Structure Vision 2010 and the New Growth Strategy.

In the Plan, three actions are formulated regarding the stable supply of resources and energy:

- promotion of strategic comprehensive resource diplomacy (action 41);
- strengthening domestic resource development (action 42) and,
- securing stable supply of rare metals and other metallic resources (action 43).

Action 41 states that Japan will 'engage in strategic, comprehensive resources diplomacy, intensively applying policy resources, with countries in which Japanese companies are expected to obtain new resource interest.' Action 42 mentions the development of seabed resources, on which more below.

Action 43 states that '[t]o address supply stoppage risk on mineral resources of rare metals including 'strategic rare metals' (rare earth, lithium, tungsten, etc.), we will work to secure overseas resources, promote recycling, develop substitute materials, and push ahead with stockpiling these materials.'<sup>166</sup>

To achieve the desired policy results, METI has requested the following budget for fiscal year 2011 to implement the following projects:

Support for the acquisition of mining rights, ¥0.35 billion;

- Establish a platform for promoting development of rare metal resources, ¥ 0.82 billion;
- Develop substitute materials for rare metals, ¥ 1.30 billion;
- Invest in or lend money to metallic mineral resources prospecting, (for all natural resources) ¥21.10 billion.<sup>167</sup>

## OTHER DOCUMENTS

Besides these initiatives focused exclusively on the mineral sector, rare metals are also mentioned in the New Growth Strategy Toward a Radiant Japan of December 2009 and the Basic Ocean Law of 2007.

### **New Growth Strategy Towards a Radiant Japan**

The New Growth Strategy of December 2009 is not a stand-alone mineral policy, but rather a comprehensive approach to bolster the Japanese economy in light of the financial crisis. Specifically, the strategy mentions rare metals and REEs in its discussion to use green innovation to spur economic growth. The strategy aims to 'realize complete cyclical use of domestic resources [of rare metals and REEs] by promoting recycling, promoting technological development of rare metals and rare earth elements that can replace existing energy resources, and advancing a comprehensive strategy to secure resources and energy.'<sup>168</sup>

### **Basic Ocean Law**

The seabed within Japan's Exclusive Economic Zone (EEZ) offers a potential source of supply of rare metals and other mineral resources. However, given the depth of these resources and the technological challenges involved, much of this deep-sea mining is prohibitively expensive. In the past a few small scale mines were developed, but when mineral demand was low they became economically unviable and were shut. With

rising demand and the declared strategy to develop alternative sources for rare metals, Japan is re-examining the development of its seabed in the Sea of Japan. In July 2007, Japan adopted the Basic Ocean Law to this end. Article 17 of the Law addresses the positive use of oceans for marine related scientific knowledge and the development of mineral resources, including manganese and cobalt ore.<sup>169</sup>

The 100 Actions Plan also addresses the development of seabed resources under action 42 (strengthening of domestic resources development). The plan states that Japan will ‘conduct a survey for exploration of cobalt-rich crust and know amounts of resources in seamounts.’<sup>170</sup> For fiscal year 2011, the Japanese government reserves ¥0.66 billion for a basic survey of deep sea-floor resources.

## MAIN ACTORS

The national debate on strategic non-fuel minerals is characterized by a unanimously shared perspective. Both governmental actors and industry believe that securing a stable supply of resources is key for the health of Japanese business and economic growth. These actors also share a common perspective on the instruments to achieve this end. It involves one, or a combination, of the following: diversification of resource supply through new sources; the development of substitutes and technologies that reduces the use of strategic resources, stockpiling and recycling.

### Government

The Japanese government’s strategy to secure strategic metals has two main dimensions, external and internal. First, Japan aims to secure overseas resources by bolstering relations with resource-rich states and by adopting ‘aggressive resources diplomacy.’<sup>171</sup> [emphasis added] In its Guidelines for Securing Natural Resources, the government stresses its support for ‘key resource acquisition projects by promoting active diplomacy and helping these projects to be strategically connected to economic cooperation measures, such as [ODA], policy finance and trade insurance.’<sup>172</sup> Key resource acquisition projects are defined as projects that involve Japanese companies and that help securing supply of resources, including rare metals and other minerals. Japan promotes strategic collaboration between governmental bodies, agencies and independent administrative institutions in implementing this policy, including METI, JOGMEC, JICA, JBIC, New

Energy and Industrial Technology Development Organization (NEDO), Japan External Trade Organization (JETO), and NEXI.<sup>173</sup>

Second, Japan aims to ensure internal availability by promoting the development of substitutes, new technology, stockpiling, alternative sources (for example from seabeds), and through recycling. Aside from the strategies mentioned above, in 2007 two research projects on rare metals were launched within the framework of the national research program Innovative Technologies on Rare Resources and Scarce Resource Substitute Material for Determining Solutions to Resource Issues.<sup>174</sup> One of the projects, the Elements Strategy Project of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) aims to develop high-functionality substances and material without using strategic non-fuel minerals and to develop substitutes from abundantly available material. Many actors are involved in this project including universities, institutes for science and technology and companies, mining companies, steel and chemical products corporations, and manufacturers of cars and high-technology consumer goods.

Another project, the Development Project on Rare Metals Substitution, sponsored by METI, is a research program whose objective is to develop technologies that reduce the use of three types of strategic materials. It focuses on achieving a 50% reduction in the use of indium for transparent electrodes, and a 30% reduction in the use of dysprosium in rare earth metal magnets and in tungsten for carbide tools.<sup>175</sup>

### **JOGMEC**

JOGMEC, a key player in the policy debate on strategic minerals, is Japan's administrative agency in charge of securing a stable supply of oil, natural gas and nonferrous metal and mineral resources. It is also charged with implementing mine pollution control measures and manages Japan's national stockpiles of rare metals.<sup>176</sup> These stockpiles are used to control prices as well as to stabilize supply in the event of an emergency.<sup>177</sup>

JOGMEC supports the government's resource diplomacy towards resource-rich countries.<sup>178</sup> In Botswana, for example, JOGMEC established a geological remote sensing centre, which serves as Japan's exploration base in southern Africa. JOGMEC's annual report of 2009 furthermore mentions activities in Brazil, Zambia, Argentina, Bolivia, the US, Chile and Australia. JOGMEC

itself also conducts resource diplomacy itself, for instance by organizing ‘Metal Saloons’, a series of forums where the Japanese and representatives from resource-exporting countries meet. It also supports the private sector with financial assistance, initial exploration and research and development expertise.<sup>179</sup> For example, JOGMEC started a research program in 2007 on recycling rare metals and in 2009 a program developing bacteria able to recover rare metals from used products.

Finally, JOGMEC has an information-sharing function. It contributes to the Japanese knowledge base on minerals by collecting, analyzing and providing information to the government, the private sector and the general public.<sup>180</sup> It maintains, for instance, the Mineral Resources Information Center - a specialist library on mineral resources open to the public. JOGMEC publishes periodical issues and books with basic information on mineral resources and it brings together professionals from the private sector and academia. JOGMEC informs the debate at the governmental level.

### **Japanese Bank for International Cooperation (JBIC)<sup>181</sup>**

JBIC’s mission is to ‘contribute to the sound development of the Japanese and international economy.’<sup>182</sup> Regarding strategic metals, JBIC supports the government’s policy objectives by ‘promoting overseas development and acquisition of strategically important natural resources to Japan’ and ‘maintaining and improving the international competitiveness of Japanese industries.’<sup>183</sup> In line with the government’s ‘aggressive resources diplomacy’, JBIC provides loans and guarantees to develop mines and mining infrastructure in resource-rich African countries. In 2007, for example, JBIC financed the development of mines and nickel production in Madagascar ‘to ensure long-term stable supply of nickel and cobalt resources to Japan.’<sup>184</sup>

### **Industry**

Japan has a relatively small mining sector. During the 1970’s, there were 246 small and medium-scale metal mines employing some 34,000 people.<sup>185</sup> Due to overseas competition, rising production costs and increases in the yen exchange rate, many mines were closed down. In 2007 only 11 mines remained operational, of which the Hishikari mine was the most significant. At the time of writing in 2010 only a few mines are operational and the mining sector is dominated by eight major mining houses: Dowa Metals &

Mining, Furukawa Metals and Resources, Mitsubishi Materials, Mitsui Mining and Smelting, Nippon Mining & Metals, Nittetsu Mining, Sumitomo Metal Mining, and Toho Zinc.<sup>186</sup>

Japan has many car manufacturers, including well-known brands Toyota, Mitsubishi and Honda. Against the background of supply risks, and in particular after the Chinese export restrictions of September 2010, Japanese car companies were forced to rethink their risk management strategies. Many of them started to research building hybrid cars without rare earth metals or to diversify their sources of supply irrespective of government action. In 2008 Toyota Tsusho Corp. – a trading company closely linked to Toyota Motor Corp. – established a rare earth mining joint venture in Vietnam. Referring to China, Toyota company spokesman Morimasa Konishi said ‘there are many risks in depending on one nation.’<sup>187</sup> Early 2010 the company set up a rare earth metal task force to explore substitutes and new ways to use recycled materials.<sup>188</sup> Honda Motor Company has been conducting similar research and development to find substitutes for rare earths.<sup>189</sup>

The same holds true for many Japanese producers of high tech appliances, such as Toshiba and Samsung. In order to secure their supply of rare minerals, these companies have started to develop alternatives or to diversify their sources of supply. Toshiba, for example, in 2009 made a deal with Kazatomprom, a state-owned company from Kazakhstan, to secure metals needed for Toshiba products. The partnership was focused on the recovery and mining of by-products from operational uranium mines, including dysprosium, neodymium and rhenium.<sup>190</sup>

Given the demand for rare metals and the efforts of the Japanese government to secure their supply, the recycling of rare metals from discarded electronic devices has become a lucrative industry in Japan. Dowa Holdings and Kosaka Smelting and Refining are leading Japanese companies in this field of ‘urban mining.’ The Japanese government refers to old computers and cell phones as ‘urban mines’ due to the high amount of rare metals they contain.

In April 2009 the Ministry of Internal Affairs and Communications called upon cell phone manufacturers to increase the recovery rate from 20% in

2008 to 30% in 2009.<sup>191</sup> In July 2009 a pilot on recycling organized by METI with 570,000 cell phones turned up 22 kg of gold, 79 kg of silver, 5,690kg of copper and 2 kg of palladium.<sup>192</sup> According to the National Institute for Materials Science, the ‘urban mining base’, in other words, the amounts of strategic metals present in electronic devices used in Japan, is the following:

- 1,700 metric tonnes of Indium (annual global consumption is 450 metric tonnes);
- 560 metric tonnes of lead (annual global consumption is 330 metric tonnes);
- 150,000 metric tonnes of lithium (annual global consumption is 21,000 metric tonnes);
- 2,500 metric tonnes of platinum (annual global consumption is 445 metric tonnes).<sup>193</sup>

This data shows that Japan’s urban mines are a source of supply that can more than meet Japan’s need for certain rare metals.

The Japanese industry shapes the policy debate in multiple ways. It is, for example, actively involved in research and development programs. Their interests are represented at the governmental level by Nippon Keidanren, Japan’s powerful business lobby. Nippon Keidanren was established in 2002 as a result of a merger between Keidanren (the Japan Federation of Economic Organizations) and Nikkeiren (the Japan Federation of Employer’s Associations). Among its members are 1,281 companies and 129 industrial organizations.<sup>194</sup>

### **Media**

Strategic non-fuel minerals regularly make headlines in the Japanese media. The main news channels reporting on strategic metals are The Japan Times Online, Nikkei Business Online and The Mainichi Daily News. These opinion makers are concerned about the impact of supply shortages on the Japanese economy. The reporting is often targeted towards businesses and focuses on those companies potentially affected by supply disruptions, mainly the car industry. Particularly following the export restrictions from China in September and October 2010 there was heightened attention for the issue.<sup>195</sup> The media also assess the measures taken by industry and government to alleviate supply risks and to ensure stable supply. Much attention is given to efforts seeking alternative methods of supply, including recycling and diversification. Deals by the government, trading companies and car manufacturers with other countries are recurrently covered.



### **Research Institutes**

Japanese research institutions share the vision that Japan needs to alleviate its mineral vulnerability and heighten its rare metal security. The measures that research institutions have recommended include the diversification of resource supply through new sources, the development of substitutes and technologies that reduce the use of strategic resources, and recycling. The institutes conduct research on technologies that can strengthen Japanese industry or create new opportunities for Japanese businesses.

#### **National Institute of Advanced Industrial Science and Technology**

The National Institute of Advanced Industrial Science and Technology (AIST) is Japan's leading public research organization. It was formed on 1 April 2001 through a merger of 15 research institutes operating under the Ministry of International Trade and Industry (MITI, reorganized as METI in 2001) and the Weights and Measures Training Institute.<sup>196</sup> In late 2010 AIST stated that there is widespread concern about energy security and that 'we must also recognize the seriousness of the problems facing the supply of rare metals due to the fact that most of rare metal deposits are located in extremely limited countries and that development of their substitution is more difficult than in the case of energy, which has several alternatives.'<sup>197</sup> In 2006 AIST established a Rare Metal Task Force to actively tackle the rare metal problem in Japan.<sup>198</sup> The objective of the Task Force was to strengthen Japan's economic security by developing resource exploration technologies, technologies to reduce rare-metal consumption, substitutes and recycling technologies. According to Mamoru Nakamura, Director of the Materials Research Institute for Sustainable Development, AIST is the only institution in Japan that is carrying out this research in such a field-integrating way.<sup>199</sup>

#### **Metal Economics Research Institute**

The Metal Economics Research Institute (MERI/J) is a non-profit research institute that is supported by Japanese non-ferrous metal industries. MERI/J was established in 1989 to promote economic research on a variety of topics related to non-ferrous metals markets.<sup>200</sup> In 2010 MERI/J had 19 Full Members and 16 Associate Members, among which were JOGMEC, JBIC, trading companies such as Sumitomo Corp. and Mitsui & Co. and other members from the industry, including companies in the field of non-ferrous metal smelting, wire and cable, brass mill, and electric utilities.<sup>201</sup> MERI/J conducts regional studies on Asian and other metal markets, research on

the technologies used in the global metal industry, on environmental aspects of the metal industry and on scrap market and recycling. MERI/J considers the continued access to these metals essential for Japan's modern industrialized society.

### CONCLUSION

For Japan, strategic non-fuel minerals are an issue of high concern due to continuous risks of supply constraints. Japan has only a small mining industry and is virtually completely import dependent for its strategic minerals. Due to the importance of high-technology industries to the overall Japanese economy, securing access to strategic materials is crucial. All actors involved in the mineral policy debate, of which METI, JOGMEC and the industry are among the most important, are fully aware of Japan's mineral policy and share the view that securing a stable supply of resources is essential for the Japanese economy and way of life. In order to address this issue, the Japanese government has developed comprehensive policies on securing strategic minerals. The four elements of the strategy are the following:

- securing overseas resources and stimulating domestic production;
- recycling;
- developing alternative materials;
- and stockpiling.

Securing strategic minerals is embedded in a broader policy of securing natural resources. With respect to this objective, the Japanese government has stated it will engage in aggressive resource diplomacy abroad. JOGMEC plays an important role in facilitating access for Japanese companies to overseas resources, particularly in Africa.

Domestically, Japan also aims to decrease its dependency on foreign strategic minerals. Large funds have been made available to research the development of substitutes and to explore new sources of supply, for instance in seabeds. Urban mining, the recycling of strategic metals from discarded devices is also upcoming and increasingly becoming a part of Japanese culture.'

Events in History	Year	Japan Mineral Policy Related Events
Start of WW II	1941	Japan faces supply disruption of steel, oil and rubber due to US economic sanctions and boycott.
		Establishment of stockpile of critical materials for military and civilian use
		Government encourages domestic industries to develop alternative sources and recycling
		7 December: Japan attacks the United States
Energy crises	1963	MMAJ is established to ensure a stable supply of non-ferrous metals and other mineral resources
	1970s	Energy crises underscore Japan's mineral vulnerability and import dependency and heighten fear of supply disruptions among policy makers
	1989	Establishment of MERI/J to promote research on non-ferrous metals markets
	2002	Establishment of Nippon Keidanren, Japan's powerful business lobby
	2004	Establishment of JOGMEC to ensure a stable supply of oil, gas and minerals
	2005	December: Resources Strategy Committee is established by the Agency for Natural Resources and Energy to examine rare metal production, supply risks and mitigation policy
	2006	AIST sets up Rare Metal Task Force

2007	July: Basic Ocean Law is enforced calling for positive use of seabed resources, including manganese and cobalt ore
	METI and MEXT launch rare metal research projects as part of 'Innovative Technologies on Rare Resources and Scarce Resource Substitute Material for Determining Solutions to Resource Issue'
	JOGMEC starts research program on recycling of rare metals JBIC funds nickel production project in Madagascar
2008	September: economic recession and Lehman Brothers, bankruptcy heightens concerns about Japan's economy and mineral vulnerability
	September: government expresses intent to formulate strategy to secure stable supplies of rare metals
	METI starts discussions in the Mineral Resources Subcommittee and Advisory Committee on Natural Resources and Energy
	Toyota Tusho Group announces REE mining joint venture in Vietnam

July: China cuts export quota to bolster prices and meet domestic demands  
 September 2010: China restricts REE exports following Sino-Japanese maritime incident

2009

July: 'Strategy for Ensuring Stable Supplies of Rare Metals' published

December: 'New Growth Strategy Toward a Radiant Japan' published

JOGMEC reports on Japan's overseas resource activities in Brazil, Zambia, Argentina, Bolivia, the US, Chile and Australia

JOGMEC starts research program on technology that uses bacteria to recover rare metals from discarded products

JOGMEC publishes Rare Metal Handbook

Toshiba starts rare metal mining joint venture in Kazakhstan

Toyota Motor Corp. sets up rare earth metals task force

July: Japanese companies express concern over China's protectionist policies

August: '100 Actions to Launch Japan's New Growth Industry' report published

September: Japanese companies report China halts rare metal exports to Japan

September -October: heightened media attention for Japanese mineral vulnerability

Nippon Keidanren urges government to take rare metals issue seriously

2010

## 2.5 CONCLUSION

The analysis of national policies on strategic non-fuel mineral resources requires a basic understanding of the technical and geological features of non-fuel minerals, an appreciation of the economic and political dynamics of mineral insecurity, as well as a grasp of the historical context that shapes individual countries' perceptions and responses to this insecurity.

Geological and technical facts alone do not explain price developments in non-fuel mineral markets, import dependence or reserve statistics. A common misperception is to think of mineral reserves in terms of static, absolute geological variables instead of appreciating their dynamic, relative and economic nature. Political, technological and economic factors determine the mutual dependencies of states with regards to non-fuel minerals, their strategic concerns, and the policies states design and implement.

The case studies presented here analyze the non-fuel mineral policies of the US, UK and Japan, three advanced industrialized countries. Our findings show that there is no common list of strategic minerals. What is considered 'strategic' differs from state to state and changes over time. The analysis indicates that strategic minerals are those that (a) are essential for the continued operation of critical sections of the national economy or to national security and (b) whose supply to the state may be interrupted through restrictions in the supply chain or at the point of sourcing. From a geopolitical perspective, these two factors may be interrelated, as producer states use ownership of particular mineral resources for political leverage. However, this may also be the result of supply restrictions due to limited points of sourcing, producing critical points of potential failure.

Looking at the development of strategic mineral policy in our three case studies, it is clear that the debate over strategic minerals is cyclical in nature, and coincides with particular events in the international system as well as the development of specific technologies. Combined, these may produce increased levels of non-fuel mineral insecurity. Historically, states have responded with a range of different policies to address such insecurity, which are informed by unique national prisms that shaped their understanding of the strategic role of non-fuel minerals and adequate policy responses. These prisms are shaped by a country's foreign policy

outlook, the composition of its economy, the international institutional setting in which it operates, its own mineral endowments and its geopolitical position.

The US has a strong national security-focused approach to strategic minerals. Japan, by virtue of its dependence on its high-tech economy and innovation-driven society, has a comprehensive perspective based on economic security interests. The UK, by contrast, gives precedence to viewing the problem as an economic trade issue and, at least until now, has been an active promoter of the virtues of free trade.

Each state has a distinct national approach to the issue of strategic minerals and while it is impossible to generalize across the board on the basis of three case studies, there are several striking commonalities. All are dependent on import for their strategic minerals, they all have expressed concern (though some more than others) over recent trade restrictions in rare earth elements (REEs) and their mineral policies have historically been impacted by similar cycles of geopolitical tensions. These geopolitical tensions, whether it was the Second World War, the Cold War, state fragility in Africa, or the global economic crisis, are the dominant factor shaping shifts in strategic mineral policy.

Beyond these commonalities there are major differences. The US has historically preferred national responses to individual instances of non-fuel mineral insecurity. The US has favoured building domestic supply chains or stockpiling the mineral in order to avoid dependence on the international market. In contrast to this, Japan pursues a comprehensive policy approach to a host of strategic minerals based on four pillars: stockpiling, developing alternatives abroad and at home, recycling and innovation. The UK concentrates on ensuring its mining companies are able to freely source necessary minerals abroad.

Given recent concerns over REEs, it now appears that countries have moved into a new cycle of strategic mineral policymaking. The impact of the world economic crisis has reinforced this trend, as Western mining companies struggle to raise the necessary capital to rapidly develop alternative sources of supply, which could make Western states less dependent on the supplies of the emboldened monopolist China. Their

crucial role in developing alternative energy sources to fossil fuels, as well as sensitive defense applications, also to the perception of REEs as indispensable strategic resource.

This trend can clearly be observed in present US and Japanese policy initiatives. While the US is likely to develop a domestic REE supply chain (comparable to its efforts to build a beryllium supply chain a decade ago) and is boosting its stockpiles, Japan has developed a comprehensive mineral policy based on assertively using development cooperation for the purpose of developing new mines abroad, but also stimulating research into substitutes, making advancements in recycling and reconsidering the composition of its stockpiles. The UK appears to lag behind in its policy response. The country emphasizes domestic production, but as of yet does not express a similar sense of urgency to develop a strategic mineral policy towards REEs as the other two states do. However, the UK's recent Strategic Defense Review calls for an appreciation of the strategic importance of REEs. This may indicate the emergence of a British strategic minerals policy with regards to these metals.

Our analysis shows that states place a clear emphasis on instruments directed at reducing their dependence on international markets for the supply of strategic minerals. Whether this is through subsidizing domestic resource production, boosting stockpiles or investing in recycling efforts, the focus lies on reducing trade dependencies. In Japan this has been expressed most vocally by pursuing 'aggressive resources diplomacy' based on developing new mining ventures in Central Asia, Africa and South America.

While during previous cycles of strategic mineral policymaking—such as during the 1980's with platinum group metals—international tensions and security concerns ultimately did not escalate and supply risks associated with import dependencies were resolved, this is no guarantee for an equally benign future. Our analysis shows that domestically-focused initiatives concerning strategic non-fuel minerals are developing today in response to growing resource nationalism in producer states. This creates the risk of a fragmentation of international markets for strategic minerals, which could further fuel security concerns, increase the potential for geopolitical tensions, and inhibit the rapid and efficient expansion of global supplies.



Therefore, cooperative efforts aimed at an efficient expansion and diversification of the global supply chain should be preferred over narrow policy instruments to establish domestic sources of supply; and should be connected to joint investments in R&D for more frugal resource use, enhanced recycling and the development of effective substitutes. Strategic mineral insecurity today does not present a problem that cannot be overcome, but it does deserve our attention.



## 3 ANNEX - DESCRIPTION OF METALS

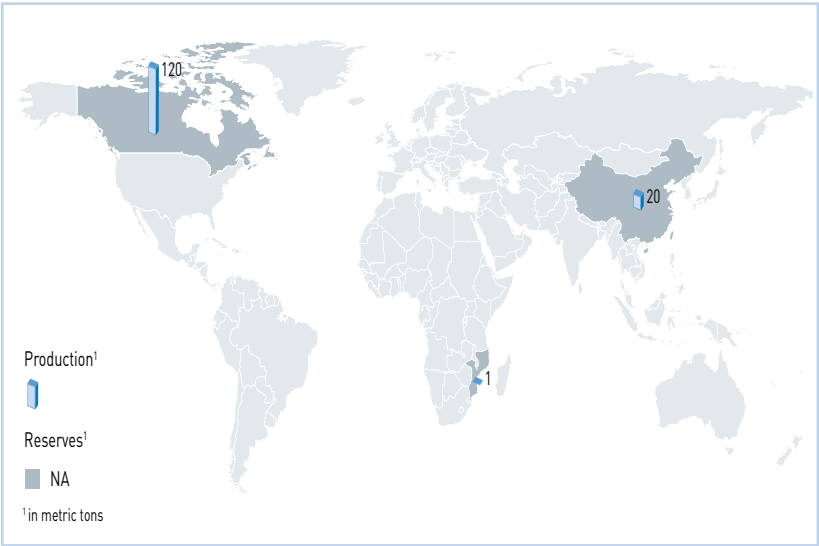
### 3.1 INTRODUCTION

This annex offers an overview of key metals and lists their most important characteristics, sources, key applications and provides information on their recycling. For many of the metals that are produced as by-products or in very small quantities, data are often not available or are withheld. Nonetheless, we have made an effort to provide as comprehensive and consistent information as possible.

In order to present the available information on a total of 37 metallic elements—some of which are part of two groups of metals, namely platinum group metals (PGMs) and rare earth elements (REEs)—systematically, we have compiled information from a variety of sources. Geological surveys, predominantly the USGS and BGS, made up the majority of references. Information from these surveys was supplemented after cross-research with sources ranging from science websites offering basic coverage of elements in the Mendeleyev system and academic assessments all the way to business websites, databases and newspaper articles covering the matter.

Given the limits on the available information, a perfect systematization and standardization of data was not possible from existing open sources. The overview we offer here depicts the most important features of key metals in a way that we hope will correspond to the needs of readers searching for an insight or to refresh their knowledge on strategically important metals.

3.2 BERYLLIUM



Key Characteristics¹	Beryllium
Formula	Be
Color	Steel-gray
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Brittle
Crystal	Hexagonal

Beryllium is an alkaline earth metal mined mainly from the minerals beryl and bertrandite. It is six times stronger than steel and has a very high melting point at 1,278 °C, but it is nonetheless lighter than aluminium.<sup>202</sup> Further unusual properties include excellent thermal conductivity, high resistance to acids and very high permeability to X-rays.<sup>203</sup>

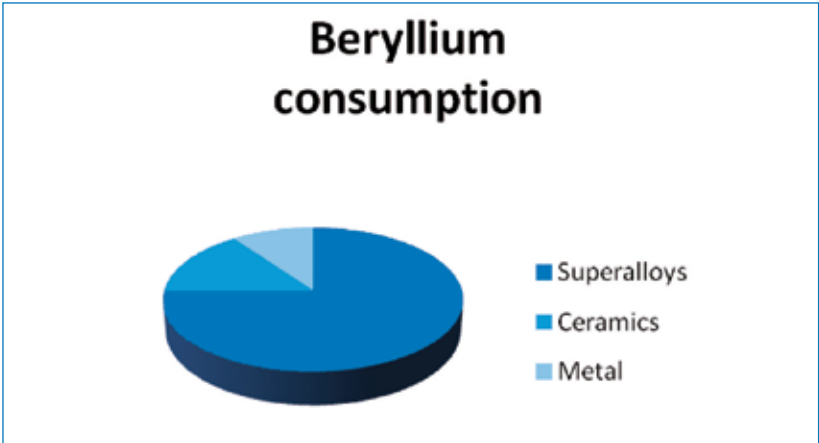
### World production and reserves

BERYLLIUM <sup>204</sup> (in metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2008/09	2008
USA	110	155	100	176	120	NA	NA
Mozambique	6	6	6	1	1	NA	NA
China	20	20	20	20	20	NA	NA
World total:	138	180	130	200	140	NA	NA

Beryllium production in the US is heavily subsidized and mainly comes from a bertrandite mine in Utah. Smaller quantities are currently being mined in China and Mozambique. Very significant quantities of beryllium concentrates exist as stockpiles in Kazakhstan, allowing for several decades of production.<sup>205</sup>

### KEY USE<sup>206</sup>

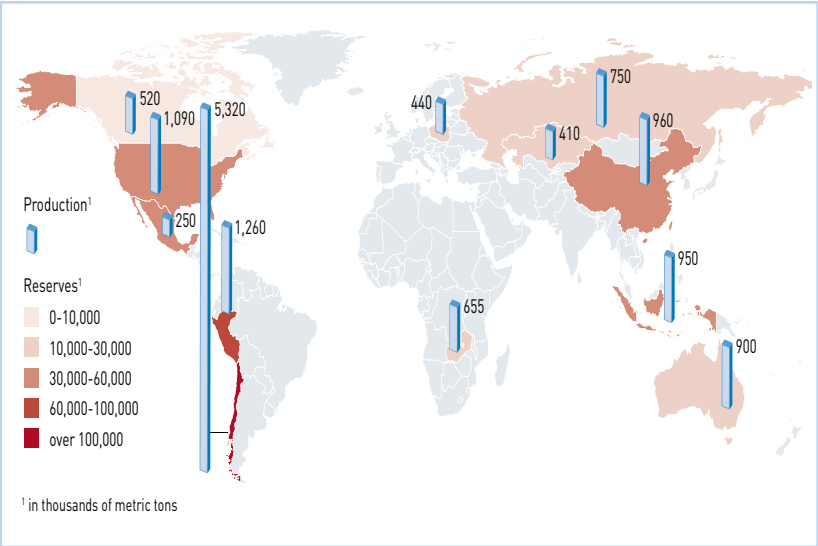
Beryllium is used in a wide range of industries, technologies and applications, such as aerospace, high performance electronics, nuclear technologies, and high-end defense technologies, including high-speed aircraft, helicopters, (nuclear) missiles, spacecraft and satellites. It is mainly connected to lightweight materials with superior thermal conductivity and excellent resistance against heat and corrosion.



**RECYCLING**

Beryllium is mostly recycled from new scrap and to a lesser extent from old scrap. In 2000 approximately 35 tonnes of beryllium where recycled in the US, with 14% of the material being harvested from old scrap.<sup>207</sup>

3.3 COPPER



Key Characteristics <sup>208</sup>	COPPER <sup>209</sup>
Formula	Cu
Color	Pale rose to copper-red, sometimes brown
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Ductile and malleable
Crystal	Cubic

A non-ferrous transitional metal element, copper is usually forming compounds. Therefore, it is rarely found in native state and mainly appears in three groups of minerals<sup>210</sup>: hypogene (chalcopyrite, bornite, enargite), copper oxides (cuprite, malachite, chrysocolla and covellite) and secondary sulphides (chalcocite and covellite). Cuprite is the mineral with the highest percentage of copper (88.8). However, the most exploited ore is the one with the lowest percentage of copper - chalcopyrite (34.6)<sup>211</sup> - since it is the most common to be found.

Copper ore appears in various deposit types. The most important ones are<sup>212</sup>: porphyry (50-60% of world production), sediment-hosted (20% of world production) and the red-bed deposits.

### World production and reserves<sup>213</sup>

COPPER (in thousand of metric tonnes)							
Country:	Mine Production					Reserves <sup>214</sup>	Reserve base <sup>215</sup>
	2005	2006	2007	2008	2009est.	2009	2009
Chile	5.320	5.360	5.560	5.330	5.320	160.000	360.000
Peru	1.010	1.049	1.190	1.270	1.260	63.000	60.000
United States	1.140	1.200	1.170	1.310	1.090	35.000	70.000
China	755	890	946	950	960	30.000	63.000
Indonesia	1.070	816	797	651	950	31.000	38.000
Australia	927	859	870	886	900	24.000	43.000
Russia	700	725	740	750	750	20.000	30.000
Zambia	436	476	520	546	655	19.000	35.000
Canada	567	607	589	607	520	8.000	20.000
Poland	523	512	452	430	440	26.000	48.000
Kazakhstan	402	457	407	420	410	18.000	20.000
Mexico	429	338	347	247	250	38.000	40.000
World total:	15.000	15.100	15.400	15.400	15.800	540.000	940.000

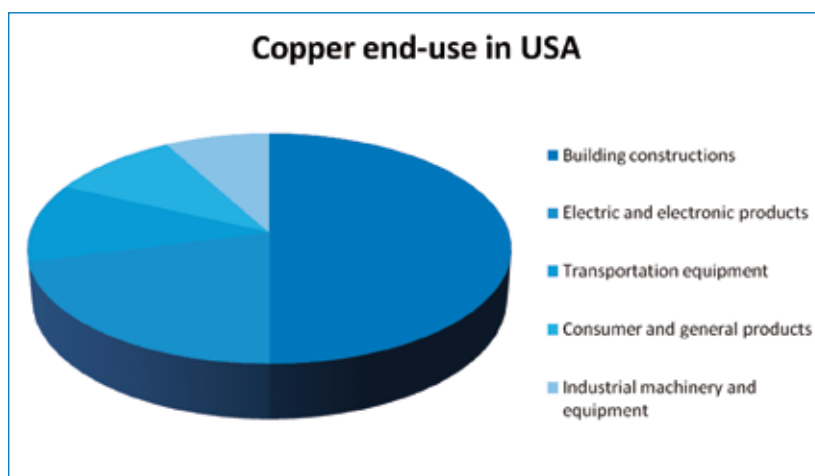
Global copper production declined in 2008 and according to USGS estimations managed to recover in 2009. The leading position of Chile as the world's greatest producer of copper (35% of overall mine production) remained intact and is likely to continue. Peru bypassed the US as the world's second biggest copper producer in 2007 and then again in 2009. Both countries contribute approximately 8% to the global mine production of copper.



### KEY USE<sup>216</sup>

Due to its conductivity, malleability and resistance, copper ranks third among the most used metals in the world. Because of its high ductility it is frequently used for wires. Combined with its ability to conduct both electricity and heat, this makes copper a material that is mainly used in the production of electrical appliances, such as electromagnets, generators, motors and communication devices.

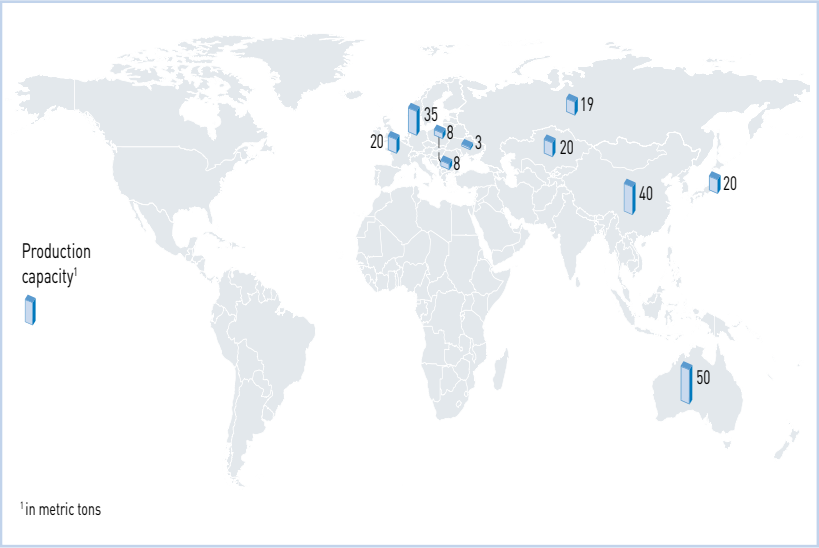
Copper alloys (such as brass and bronze) and their resistance to corrosion have proved useful in the production of plumbing pipes, roofing as well as in domestic appliances production.<sup>217</sup>



### RECYCLING

According to the UK Geological Survey, secondary production based on recycling of copper scrap was two thirds of the total world production of copper. Both copper and its alloys can be recycled multiple times as they do not lose their properties in the process. The secondary production of refined copper was constantly increasing in the last five years. While it was 2,069 thousands of metric tonnes in 2004 (world total), more than 2,900 thousand metric tonnes of secondary refined copper was produced in the world in 2009.<sup>218</sup>

3.4 GALLIUM



Key Characteristics <sup>1</sup>	GALLIUM <sup>219</sup>
Formula	Ga
Color	Silvery white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Ductile and malleable
Crystal	Orthorhombic

Gallium is a chemical element that is never found pure but in a compounded state. It is extracted as a by-product from diaspore, germanit, bauxite and zinc-based ores. It is a poor metal with a low melting point (30°C) and with one of the longest liquid ranges among metals.<sup>220</sup> Its unusual characteristics include that it expands when freezing (up to 3.1%) and that is not as good an electric conductor as some other poor metals.<sup>221</sup> Gallium-dominated minerals are: gallite, gallobeudantite, sohngeite and tsumgallite<sup>222</sup> yet none of them are of industrial importance.

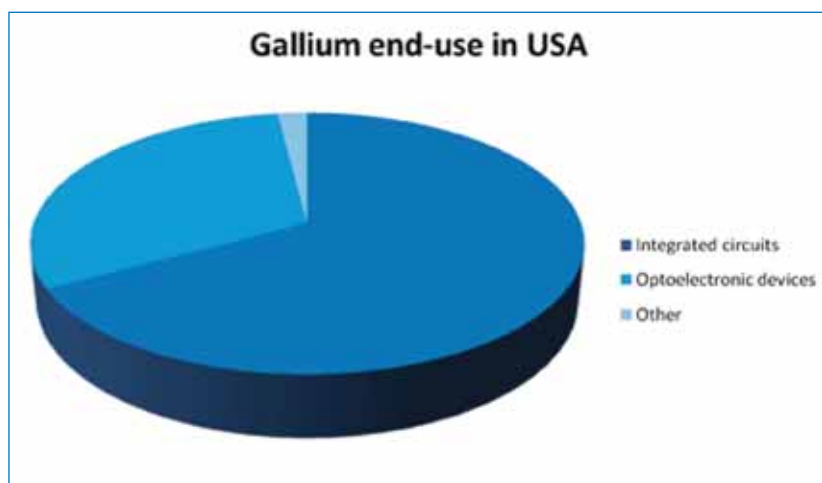
### World production and reserves

GALLIUM <sup>223</sup>					
Country	Primary production (metric tonnes)				
	2004	2005	2006	2007	2008
CPE <sup>225</sup>	25	28	30	30	30
OECD	10	10	11	10	10
EU	6	5	5	5	5
In percentages					
CPE	71.43	73.68	73.17	75.00	75.00
OECD	28.57	26.32	26.83	25.00	25.00
EU	17.14	13.16	12.20	12.50	12.50
World production capacity of crude gallium (tonnes) <sup>226</sup> :					
Australia 50			Japan 20		
China 40			Russia 19		
Germany 35			Hungary 8		
Kazakhstan 20			Slovakia 8		
France 20			Ukraine 3		

According to the USGS, the world mine production of gallium in 2009 was 78 metric tonnes, which represents a decline by one third from 111 metric tonnes production in 2008. The biggest producers of refined gallium are the USA, China and Japan, while the primary production is considered to be the highest in Australia, China and Germany.<sup>227</sup>

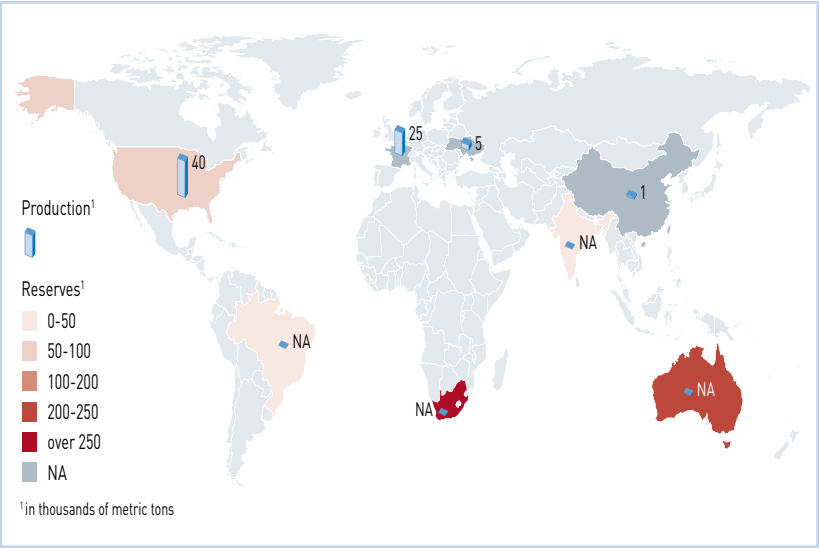
**KEY USE**<sup>228</sup>

Due to its already mentioned low melting-point and wide liquid range, gallium is used in high-temperature thermometers<sup>229</sup>. Gallium arsenide (GaAs) and gallium nitride (GaN) are used in advanced semiconductors for microwave transceivers, DVD's, laser diodes in compact discs and other electronic applications.<sup>230</sup> It is also employed as a semiconductors, doping material and in the manufacture of solid-state items such as transistors.<sup>231</sup> Gallium is used for wetting glasses to make brilliant mirrors, and in commercial ultraviolet activated phosphors when combined with magnesium (magnesium gallate).<sup>232</sup>

**RECYCLING**

Germany and Japan, along with the UK and the USA, are the leaders in gallium scrap recycling operations.<sup>233</sup> Global recycling capacity for gallium was estimated to 78 tonnes in 2007<sup>234</sup>, while the Mining Journal estimates recycling gallium capacities to be half of the world's total production of this metal.<sup>235</sup> New GaAs (gallium arsenic) scrap is recycled in the USA (mostly by Recapture Metals at its Blandings, Utah plant), Germany (by Recylex Group), Japan and the U.K. (by MCP).<sup>236</sup>

3.5 HAFNIUM



Key Characteristics <sup>1</sup>	HAFNIUM <sup>237</sup>
Formula	Hf
Color	Silvery gray
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Ductile
Crystal	Hexagonal

The transitional, ductile metal hafnium is characterized by an impenetrable oxide film that forms on its surface, making it highly resistant to corrosion. This resistance is its most important feature as it also defies attacks by alkalis and acids (all but hydrofluoric acid). Hafnium cannot be found in pure form but only in compounds with zirconium which it shares similar chemical and physical characteristics, making their separation difficult. Hafnium is the only mineral registered by the International Mineral Association (IMA)<sup>238</sup> containing high percentages of hafnium (58.45%)<sup>239</sup>. However, industrial extraction happens mainly from zircon (mineral containing hafnium and zirconium – (4.69% and 43.14%)<sup>240</sup> and baddeleyite<sup>241</sup>, though hafnium can also be a by-product of zirconium metal processing.

World production and resources

Hafnium <sup>242</sup> (thousand metric tonnes)			
Country	Primary production <sup>243</sup> (est. metric tonnes)	Reserves (metric tonnes)	Resources (est. million of tonnes)
South Africa	NA	280	NA
Australia	NA	230	NA
United States	40	68	14
Brazil	NA	44	NA
India	NA	42	NA
France	25	NA	NA
Ukraine	5	NA	NA
China	1	NA	NA
World total	71	660	60

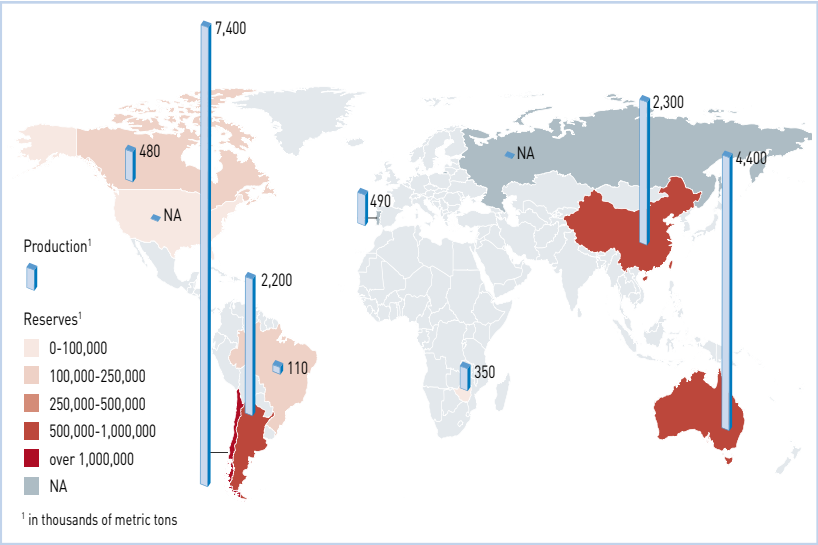
KEY USE

There are two main uses of hafnium. It is mostly used in nickel-based alloys to create so-called superalloys, withstanding high-stress and high temperatures situations. Due to its neutron-absorbance ability, it is also used in nuclear reactors (including those of nuclear submarines) in control rods<sup>244</sup>. Another use of hafnium has been announced in 2007 when Intel started producing working versions of hafnium-based chips indicating possible substitution of silicon-based transistors.<sup>245</sup>

RECYCLING

No data available

3.6 LITHIUM



Key Characteristics	LITHIUM <sup>246</sup>
Formula	Li
Color	Silvery
Streak	White
Transparency	Opaque
Luster	Metallic
Tenacity	Malleable and ductile
Crystal	Cubic

Lithium, alkaline and the least dense of all metals can be found in two basic types of deposits: continental brines and hard rock ore.<sup>247</sup> Its high reactivity makes it difficult to be found in its native state, so it is usually compounded in complex minerals. There are 109 registered minerals containing lithium, of which lepidolite, petalite and spodumene are the most used. The last mineral to be found so far, in 2006, jadarite, is still examined for industrial usefulness.

### World production and reserves

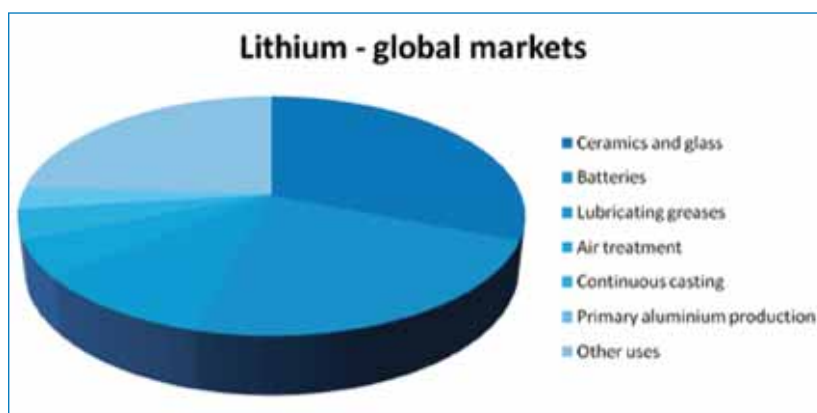
LITHIUM (in thousand of metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2009	2009
Chile	8.270	8.200	11.100	10.600	7.400	7.500.000	3.000.000
Australia	3.770	5.500	6.910	6.280	4.400	580.000	220.000
China	2.820	2.820	3.010	3.290	2.300	540.000	1.100.000
Argentina	1.980	2.900	3.000	3.170	2.200	800.000	NA
Portugal	320	320	570	700	490	NA	NA
Canada	707	707	707	690	480	180.000	360.000
Zimbabwe	260	600	300	500	350	23.000	27.000
Brazil	242	242	180	160	110	190.000	910.000
Bolivia	-	-	-	-	-	-	5.400.000
United States	W	W	W	W	W	38.000	410.000
Russia	2.200	2.200	NA	NA	NA	NA	NA
<b>World total:</b>	<b>20.600</b>	<b>23.500</b>	<b>25.800</b>	<b>25.400</b>	<b>18.000</b>	<b>9.900.000</b>	<b>11.000.000</b>

Chile and the USA are world leaders in primary lithium production, yet, the exact data on the mine production of lithium by the USA are withheld and therefore not available to the public. With the discovery of important sources of lithium bearing ore in the Andes, Argentina also became one of the bigger producers. Nevertheless, its production is significantly lower than Chile's whose main source of lithium brines lays in the infamous Atacama Desert.<sup>248</sup>



### KEY USE<sup>249</sup>

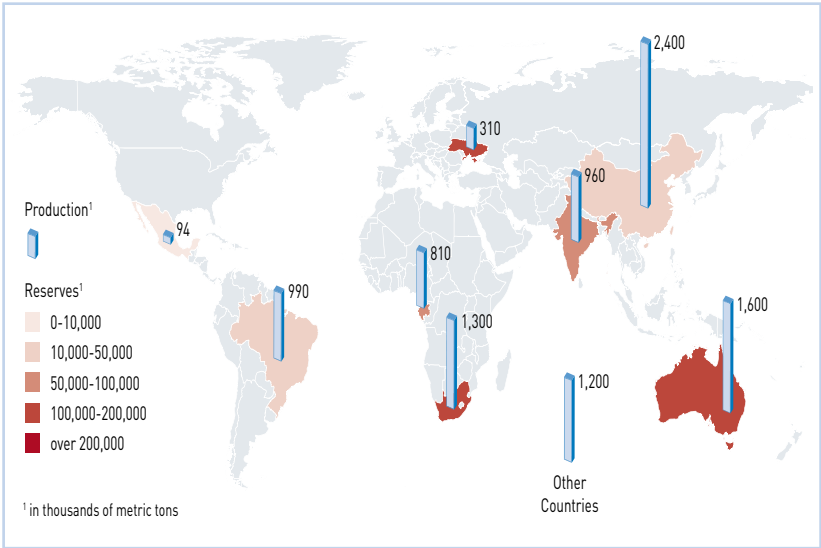
Lithium first became an important industrial material in anode production. Nowadays, it is mostly used in ceramic and glass and lithium-ion batteries production. Due to its chemical characteristics it is mainly exploited by the pharmaceutical industry to produce mood stabilizers. Lithium also has a nuclear application. It was used as a fusion fuel in the first versions of the hydrogen bomb. It is now used in nuclear plants and reactors. Probably the most promising industrial use of lithium is in re-chargeable batteries for electric cars, which are considered to be the vehicles of the future.



### RECYCLING

Lithium recycling appears not to be as important now as it might be in the future, given the increasing demand for clean energy and electric vehicles. So far, there are no official data on recycling worldwide and the companies equipped to do so are few. The biggest one is Toxco Inc, a US-based company, which introduced patented process for primary recycling of lithium batteries as early as 1992.

3.7 MANGANESE



Key Characteristics	MANGANESE <sup>250</sup>
Formula	Mn
Color	Gray-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Brittle
Crystal	Cubic

Manganese is a transitional element often found in pure state or in iron compounds. There are 494 registered minerals containing manganese, of which pyrolusite and rhodochrosite are the minerals that are mostly used for primary production of manganese. Main ore deposits are deep-sea nodules, created when water from hot springs meets cold deep ocean water. However, the exploitation of nodules is not cost-efficient despite their relatively high percentage of the metal (25%). When alloyed, this transitional metal is magnetic and when alloyed with iron it becomes harder and at the same time deoxidizing, which is why it is used a lot in steel production.

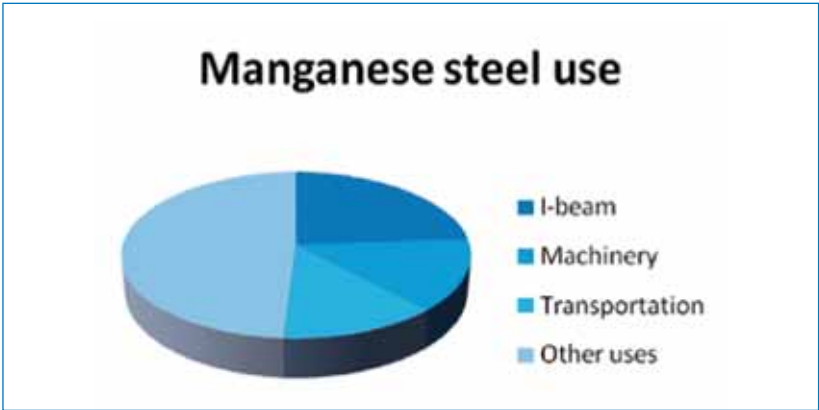
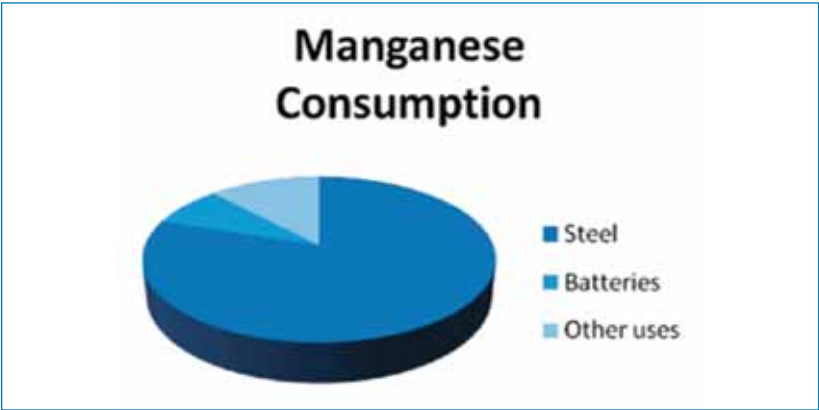
### World production and resources

MANGANESE							
(in thousand of metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2009	2009
China	1.100	1.600	2.000	2.200	2.400	40.000	100.000
Australia	1.450	2.190	2.540	2.320	1.600	87.000	160.000
South Africa	2.100	2.300	2.600	2.900	1.300	130.000	4.000.000
Brazil	1.590	1.370	933	1.380	990	29.000	57.000
India	640	811	900	960	960	56.000	150.000
Gabon	1.290	1.350	1.490	1.600	810	52.000	160.000
Ukraine	770	820	580	490	310	140.000	520.000
Mexico	180	133	125	170	94	4.000	9.000
Other Countries	1.390	1.360	1.420	1.310	1.200	Small	Small
World total:	10.500	11.900	12.600	13.300	9.600	540.000	5.200.000

After a period of steady growth in manganese mine production (approximately 3% per year), there has been a significant decline in 2009 according to the USGS estimations. The production decreased by almost a third and it occurred mostly due to the significant decreases in Brazil's and Gabon's production of manganese ore. <sup>251</sup>

### KEY USE <sup>252</sup>

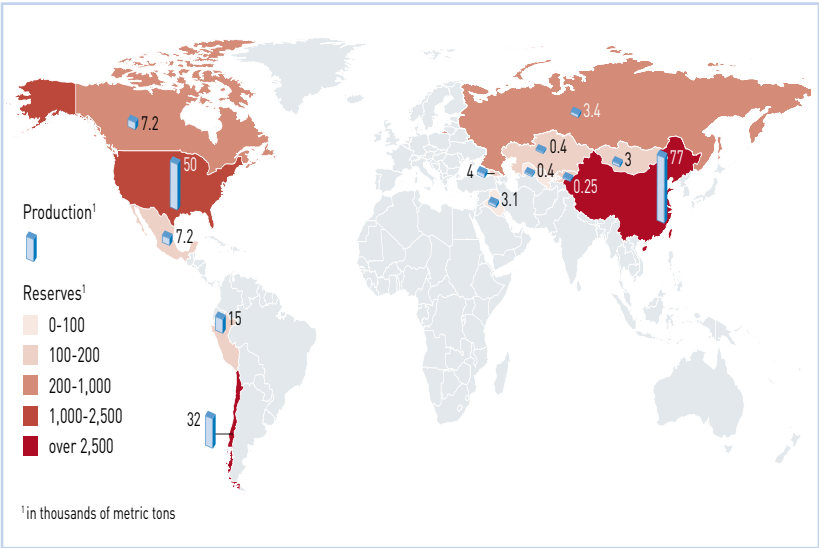
Apart from steel production, manganese is also used in various other fields, such as production of alkaline batteries which are expected to be substituted completely by lithium-ion ones, in decolorizing (or colorizing) glass and as micronutrient for animal food and plant fertilizers. It is also used, as potassium permanganate, as a bactericide and algacide in water and water-waste treatments.



**RECYCLING**

There is not much information on manganese recycling. It is usually incidentally recycled as a by-product of ferrous and nonferrous scrap. The latest and only available official data on manganese recycling date from 1998 and are from the USA. According to these data, the recycling efficiency for old scrap was only 53%. As this number shows the ratio between the amount of scrap recovered and reused and the amount of available scrap, that a lot of manganese was lost in the procedure. It is our estimate that the biggest part of future manganese secondary scrap will be turned into alkaline manganese batteries.

3.8 MOLYBDENUM



Key Characteristics	MOLYBDENUM <sup>253</sup>
Formula	Mo
Color	Silvery-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Relatively ductile
Crystal	Cubic

Molybdenum does not appear as a free element in nature but is primarily extracted from the mineral molybdenit or as a by-product in mining processes of copper and tungsten.<sup>254</sup> Out of 44 registered molybdenum-based minerals<sup>255</sup> only three are regularly used for industrial purposes. Those are molybdenit, wulfenite and powellite.<sup>256</sup> One of the most important characteristics of this metal is its high melting point (sixth of all elements) at 2623°C, which makes it very useful in making heat-resistant alloys.

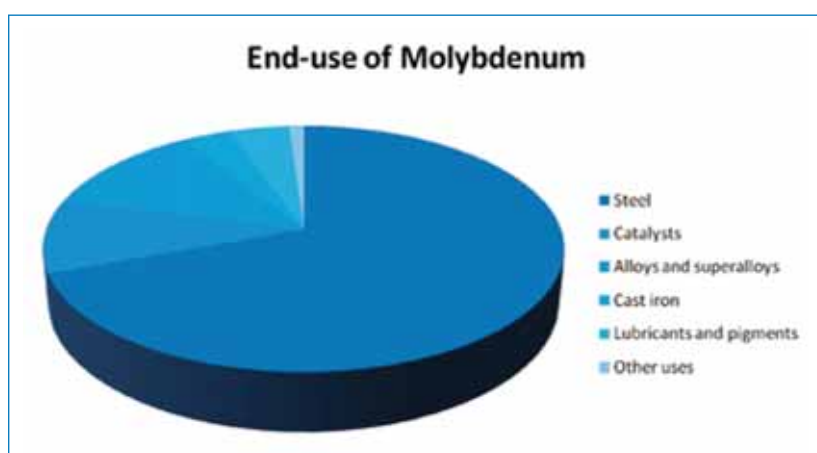
### World production and reserves

MOLYBDENUM							
(in metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
						(thousand m. tonnes)	
	2005	2006	2007	2008	2009est.	2009	2009
<b>China</b>	40.000	43.900	59.800	81.000	77.000	3.300	8.300
<b>United States</b>	58.000	59.800	57.000	55.900	50.000	2.700	5.400
<b>Chile</b>	47.748	43.278	44.912	33.700	32.000	1.100	2.500
<b>Peru</b>	17.325	17.209	16.737	16.700	15.000	140	230
<b>Canada</b>	7.910	7.270	12.000	7.720	7.200	450	910
<b>Mexico</b>	4.246	2.500	2.500	7.810	7.200	135	230
<b>Armenia</b>	2750	3.000	4.080	4.250	4.000	200	400
<b>Russia</b>	3.000	3.100	3.300	3.600	3.400	240	360
<b>Iran</b>	2.000	2.000	2.600	3.800	3.100	50	140
<b>Mongolia</b>	1.188	1.200	1.300	2.000	3.000	100	50
<b>Kazakhstan</b>	230	250	400	400	400	130	200
<b>Uzbekistan</b>	500	600	600	500	400	60	150
<b>Kyrgyzstan</b>	250	250	250	250	250	100	180
<b>World total:</b>	185.000	184.000	205.000	218.000	200.000	8.700	19.000

The production of Molybdenum is primarily concentrated in China, USA, Chile and Peru. Together, these four countries produce as much as 7/8 of the global mine production. These countries minus Peru also hold 83% the of world's manganese reserve.<sup>257</sup>

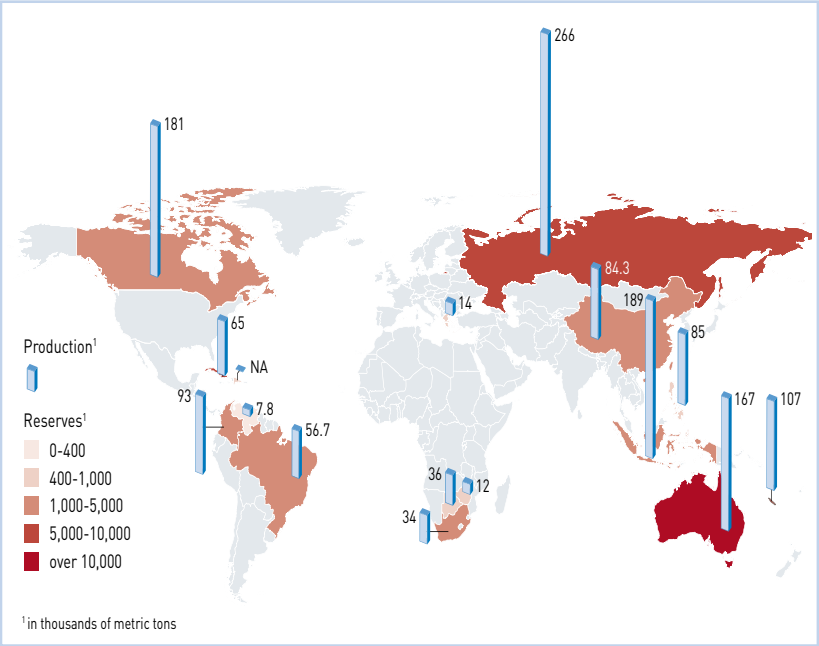
**KEY USE**<sup>258</sup>

With an extremely high melting point and corrosiveness only at elevated temperatures, molybdenum has extensive industrial use when alloyed with nickel. It is also used in steel production as it enhances its strength and hardness. Molybdenum is also used in the chemical industry as a pigment or lubricant.<sup>259</sup> In the USA 88% of national molybdenum consumption is used in the metallurgical industry.

**RECYCLING**

Molybdenum is rarely recycled on its own, but usually gets reutilized in the process of recycling steel alloys scrap. USGS estimates the amount of molybdenum reused in this process as high as 30% of the molybdenum supplies.<sup>260</sup>

3.9 NICKEL



Key Characteristics	NICKEL <sup>261</sup>
Formula	Ni
Color	Silvery-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Ductile and malleable
Crystal	Cubic



This lustrous, transitional metal is the fifth most common element on the planet. It appears in serpentinized mafic and ultramafic rocks<sup>262</sup>, magmatic sulfides and laterites, mostly as a pentandlite, industrially the most exploited of 137 registered minerals bearing nickel. Other important sources of nickel are pyrrhothite, garnierite and nickeliferous limonite. Nickel can also be extracted as a by-product from copper production. Its high suitability to make alloys makes it appropriate for various industrial uses, especially as it adds to corrosion resistance and magnetic qualities.<sup>263</sup>

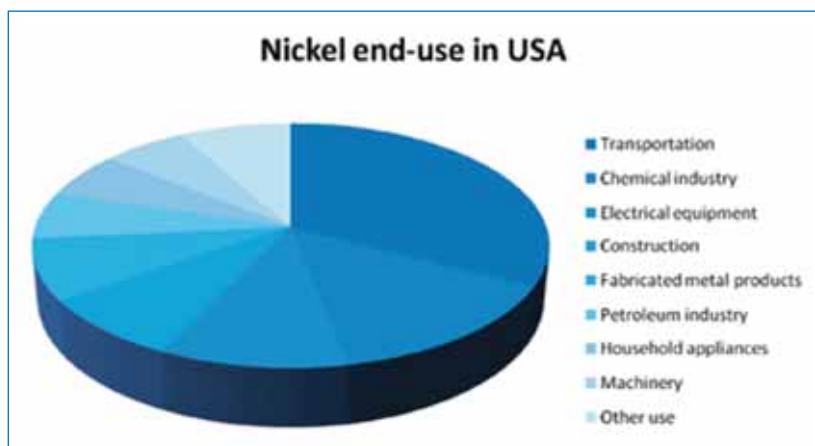
### World production and reserves

NICKEL (in metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2009	2009
Russia	315.000	320.000	280.000	277.000	266.000	6.600.000	9.200.000
Indonesia	160.000	140.000	229.000	193.000	189.000	3.200.000	13.000.000
Canada	198.000	233.000	255.000	260.000	181.000	4.100.000	15.000.000
Australia	189.000	185.000	161.000	200.000	167.000	26.000.000	29.000.000
New Caledonia	112.000	103.000	125.000	103.000	107.000	7.100.000	15.000.000
Colombia	89.000	94.100	101.000	76.400	93.000	1.700.000	2.700.000
Philippines	26.600	58.900	79.500	83.900	85.000	940.000	5.200.000
China	77.000	82.100	85.000	68.400	84.300	1.100.000	7.600.000
Cuba	72.000	75.000	75.000	67.300	65.000	5.500.000	23.000.000
Brazil	52.000	82.500	75.300	58.500	56.700	4.500.000	8.300.000
Botswana	28.000	38.000	38.000	38.000	36.000	490.000	920.000
South Africa	42.500	41.600	37.900	31.700	34.000	3.700.000	12.000.000
Dominican Republic	46.000	46.500	47.100	31.300	NA	840.000	1.000.000
Greece	23.200	21.700	21.200	18.600	14.000	490.000	900.000
Zimbabwe	9.500	8.820	7.120	13.000	12.000	490.000	260.000
Venezuela	20.000	20.000	20.000	8.140	7.800	57.000	630.000
World total:	1.490.000	1.580.000	1.660.000	1.570.000	1.430.000	71.000.000	150.000.000

The global nickel mine production declined in 2008 and 2009. Although some countries increased their production, such as Zimbabwe, China and Colombia, the decrease in others was too significant to maintain the same level of world production. The countries experiencing the biggest fall down in primary nickel production from 2007 are Russia, Canada and Australia, all three being among the top five producers.

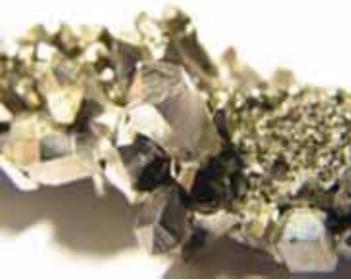
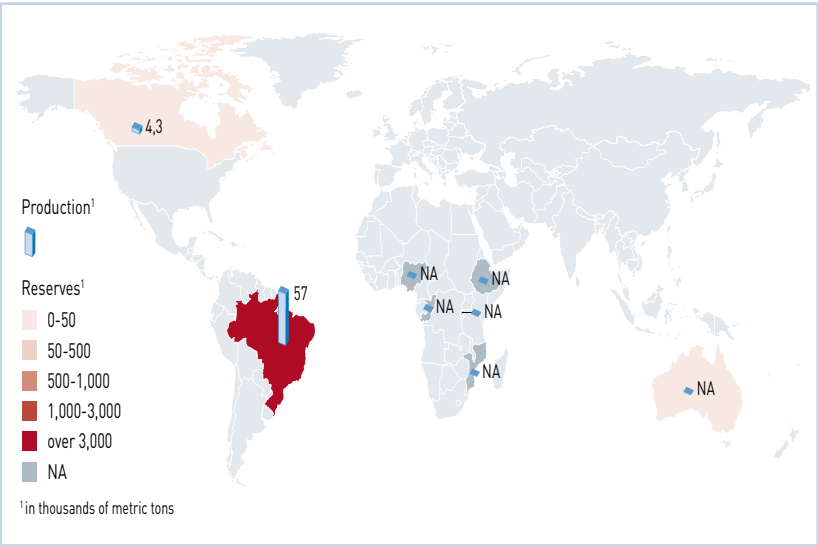
**KEY USE**<sup>264</sup>

According to both the USGS and BGS, 80% of the world consumption of nickel consists of alloys (stainless steel, ferrous and non-ferrous alloys) out of which only 12% are non-ferrous ones. Among its other uses are CD production, where it is used in electro-plating and the production of fertilizers, pesticides and fungicides.<sup>265</sup>

**RECYCLING**

Nickel is ideal for recycling due to its corrosion resistance.<sup>266</sup> However, though successfully recycled from alloys (except for the special alloys where the trend is not to recycle it separately), nickel is not easy to be recycled from catalysts in the petroleum industry. After the EU published its 'Batteries Directive' in 2006 all nickel-cadmium batteries became classified as dangerous waste in Europe. The goal was set to collect 80% of all used batteries of this kind.

3.10 NIOBIUM



Key Characteristics	NIOBIUM <sup>267</sup>
Formula	Nb
Color	Gray-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Ductile and malleable
Crystal	Cubic

Niobium, also known as columbium, is a rare metal which can be found in niobite, niobite-tantalite, pyrochlore and euxenite. Its traces are detected in as many as 123 minerals.<sup>268</sup> Deposits associated with niobium are usually carbonatites consisting mainly of pyrochlore.<sup>269</sup> As it is highly reactive with oxygen and carbon as well as with nitrogen and sulfur – niobium requires careful and protective handling. Small quantities of niobium are extracted as by-product of tantalite, tin slug and struverite processing.

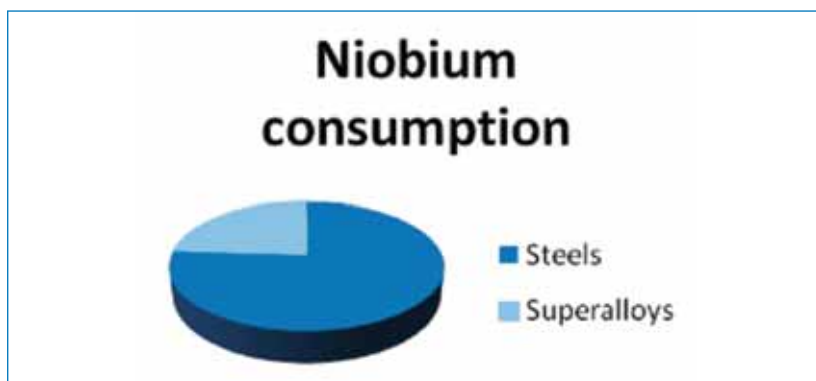
### World production and reserves

NIOBIUM (in metric tonnes)							
Country:	Mine Production					Reserves Reserve base	
	2005	2006	2007	2008	2009est.	2008/09	2008
Australia	200	200	NA	NA	NA	21.000	320.000
Brazil	35.000	40.000	57.300	58.000	57.000	2.900.000	2.600.000
Canada	3.310	4.167	3.020	4.380	4.300	46.000	92.000
Congo	25	NA	NA	NA	NA	NA	NA
Ethiopia	7	11	NA	NA	NA	NA	NA
Mozambique	34	29	NA	NA	NA	NA	NA
Nigeria	40	35	NA	NA	NA	NA	NA
Rwanda	63	80	NA	NA	NA	NA	NA
World total:	38.700	44.500	60.400	62.900	62.000	2.900.000	3.000.000

According to publicly available information, Brazil is by far the largest producer of niobium with main deposits located in Araxa, Minas Gerais state. Canada is also considered to have a significant source of niobium containing ore. In most of the other primary producer countries niobium is recovered as a by-product of the tantalum mining.

### KEY USE<sup>270</sup>

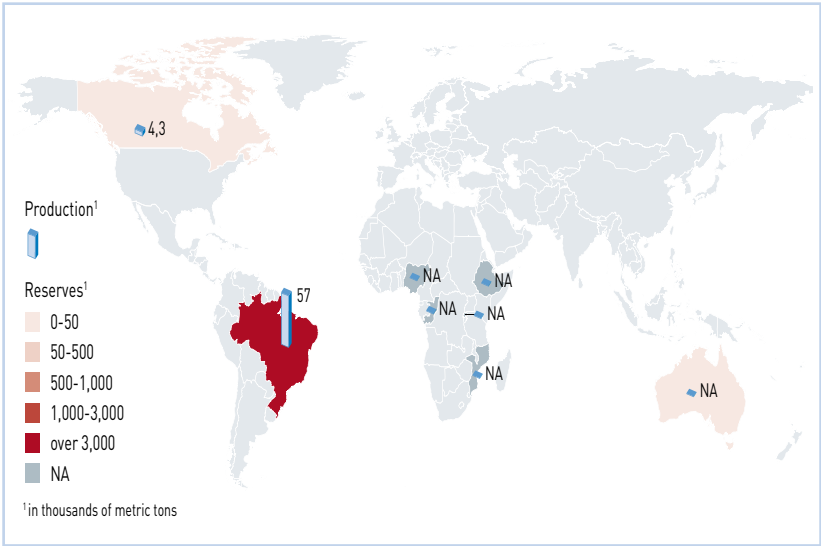
Apart from being a very important alloying agent, niobium is used in the production of jewellery. Its most important application is in combination with titanium for the production of superconductive wires. These wires are used for the creation of superconductive magnets. Stainless steel with niobium is widely used: from nuclear reactors and missiles to cutting instruments and pipelines.



## RECYCLING

Information on world-wide recycled niobium scrap is not available, but it is estimated at approximately 20% of apparent consumption.<sup>271</sup> In the USA, for example, niobium is recycled with alloys while niobium-dominated scrap recycling is negligible.<sup>272</sup>

3.11 PLATINUM GROUP METALS



Key Characteristics	PLATINUM <sup>273</sup>
Formula	6 metal elements (Ru, Os, Rh, Ir, Pd and Pt)
Color	Dark
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Malleable and ductile

The platinum group metals, frequently referred to as PGMs or platinoids, are a group of six elements with similar chemical features that are usually found together in deposits. These elements are: ruthenium, rhodium, palladium, iridium, osmium and platinum. Only two of them, palladium and platinum, can be found in pure form in nature while all others are found alloyed either with gold or with platinum.<sup>274</sup> As a group they belong to very scarce elements. Platinum (the main source of production) is usually found as fine grains or flakes but rarely as large nuggets<sup>275</sup> in ultramafic rocks such as peridotite, but can also be extracted from sulfide minerals pyrrhotite, chalcopyrite or pentlandite.<sup>276</sup> PGMs are also produced as by-products of copper and nickel mining.

**Ruthenium**<sup>277</sup> (Ru) is a hard white metal of low reactivity that oxidizes only at temperatures higher than 800°C. Due to its hardness, it is used alloyed with platinum and palladium but its main use is in catalysts and electronic applications. It is always used in small quantities but it is considered to be one of the cheaper PGMs.

**Rhodium**<sup>278</sup> (Rh) is a highly reflective, hard and durable metal with an even higher melting point than platinum. This silvery-white element is extremely resistant to corrosives and is mainly used in platinum and palladium alloys to which it adds hardness. It is applied, as most of the PGMs, as catalyst but also, due to its low electrical resistance, as an electrical contact material. High reflectivity and colour make this element one of the most used PGMs in jewellery production.

**Palladium**<sup>279</sup> (Pd) is more frequent than most of the other PGMs in the earth's crust (5 to 1 parts per billion). This lustrous silvery coloured metal is very ductile and malleable and it can be beaten into leafs (similar to gold). It is famous for its oxygen absorbance capacities as it can absorb as much as 900 times its own volume of oxygen expanding visibly in the process.

**Iridium**<sup>280</sup> (Ir) is a white metal with a hinge of yellow. Its salts, though, are very colourful. As a very hard and brittle element it is difficult to process. It is known as a corrosive resistant metal and is thus used in anti-corrosive alloys. Other main uses include platinum alloys (hardening effect), high-temperature appliances as well as tipping pens and compass bearings when alloyed with osmium.

**Osmium**<sup>281</sup> (Os) is, with ruthenium, the hardest of all metals which makes it almost unworkable. This bluish-white element is, therefore, mainly used as a hardener in alloys but it is also used in medical implants and in fingerprints detection technologies.

**Platinum**<sup>282</sup> (Pt), due to its beauty, has been used in jewellery production for centuries. It is categorized among the precious metals and its price is comparable to gold, sometimes even exceeding it. It also serves to make sealed glass electrodes, due to its expansionary qualities, but it can also be found in, for example, antipollution devices in vehicles.

### World production and reserves

Platinum						
Country	Mine Production (kg)					Reserves (PGMs)
	2005	2006	2007	2008	2009	2009
South Africa	169.000	170.000	166.000	146.000	140.000	63.000.000
Russia	30.000	29.000	27.000	23.000	20.000	6.200.000
Zimbabwe	NA	5.100	5.300	5.640	6.000	NA
Canada	6.400	9.000	6.200	7.000	5.000	310.000
United States	3.920	4.290	3.860	3.580	3.800	900.000
Colombia	1.080	1.100	1.400	1.500	1.200	NA
World total	217.000	221.000	213.000	189.000	178.000	71.000.000

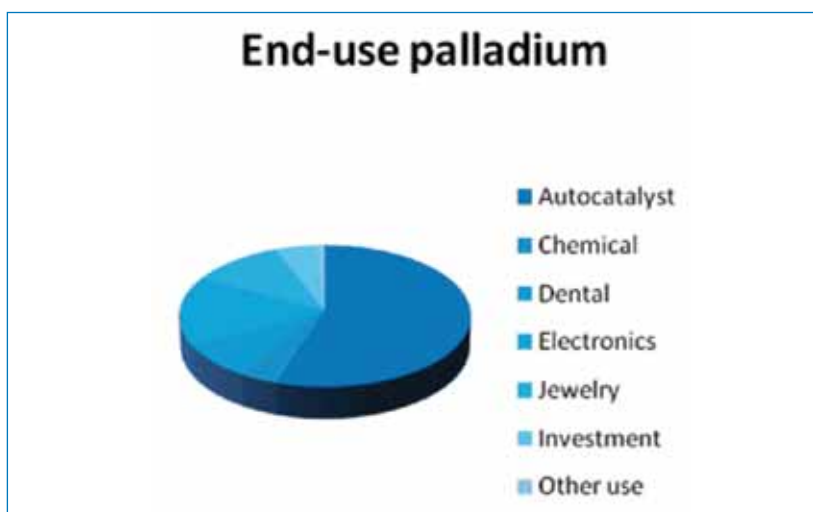
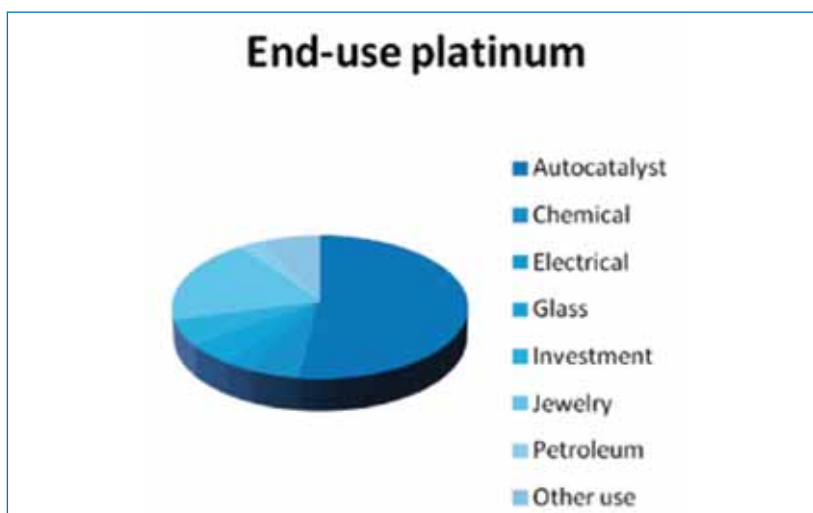
Palladium						
Country	Mine Production					Reserve base (PGMs)
	2005	2006	2007	2008	2009	
Russia	97.400	98.400	96.800	87.700	80.000	6.600.000
South Africa	84.900	85.000	86.500	75.500	79.000	70.000.000
United States	13.300	14.400	12.800	11.900	12.500	2.000.000
Canada	13.000	14.000	10.500	15.000	9.000	390.000
Zimbabwe	NA	4.000	4.200	4.390	4.800	NA
World total	219.000	224.000	219.000	204.000	195.000	80.000.000

In comparison to its peak in 2006, the world primary production of PGMs decreased for almost 20% in 2009. Apart from Zimbabwe which has steadily increased its production, other major producers, especially South Africa, Canada and Russia, have had a significant and constant decline.



**KEY USE<sup>283</sup>**

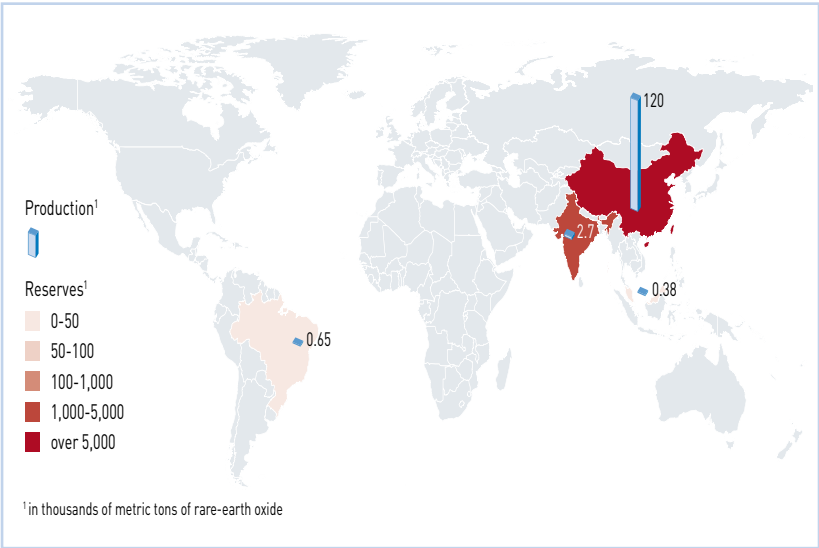
All PGMs function as catalyst so they are used as process catalysts or in emission control systems. Due to their strength and anti-corrosiveness they have other applications as diverse as jewellery production or petroleum refining. Less scarce than the others from the group, platinum and palladium are the most used.



## RECYCLING

The recovery of PGMs, mostly platinum and palladium, is the most efficient from autocatalysts. According to the US Geological Survey platinum recovery rose by 7% in 2008 reaching 31.300kg, while palladium recovery was even more successful with a rise of 15% and 36.400kg recovered worldwide. One US-based company, Stillwater Mining Co., recovered as much as 12.400kg of PGE's in its recycling program.

3.12 RARE EARTH ELEMENTS



Key Characteristics	REEs <sup>284</sup>
Formula	Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu
Color	Iron-grey to silvery
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Malleable and ductile

There are 17 elements known as are Earth Elements or REEs. Those are: Scandium (Sc), Yttrium (Y), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb) and Lutetium (Lu). All these metallic elements have similar chemical features and, although called Rare Earth Elements, they are more abundant than, for example, silver. Some of them are more common (cerium with 33ppb) while others can be found only in traces, like promethium and lutetium (0.3ppb). This group of elements contains a large sub-group called lanthanides which includes all mentioned elements except Scandium and Yttrium, which are considered REEs due to their chemical and physical properties similar to the elements in the rest of the group. REEs can be found in several types of minerals like halides, carbonates, oxides and phosphates. There are approximately 200 minerals containing REEs although only three are considered to be of major industrial use: bastnäsite, monazite and xenotime.<sup>285</sup> REEs are often produced as a by-product of iron, copper, uranium, phosphates and gold mining.<sup>286</sup>

**Scandium**<sup>287</sup> (Sc) is a very soft, light metal with a relatively high melting point (higher than for example aluminium), which makes it particularly interesting to spacecraft designers and constructors. Due to the fact that it is more expensive than aluminium, however, it is less used. Another well-known use is in the production of high-intensity lights.

**Yttrium**<sup>288</sup> (Y) is a lustrous, silvery metal, often used to increase the strength of aluminium and magnesium alloys. As yttrium oxide it is used in high-temperature superconductors and in phosphors used to provide the colour red in TV tubes. Its radioactive isotope is used in cancer treatment.

**Lanthanum**<sup>289</sup> (La) is one of the rare metals that is so soft it can be cut with a knife. This silvery, white element is one of the highest reactive metals that directly reacts with halogens, but also with elementals such as nitrogen or sulphur. In large quantities this REE is used in batteries for hybrid vehicles and as an oxide it is used for camera and telescope lenses.

**Cerium**<sup>290</sup> (Ce) is considered to be the most abundant of all REEs. This ductile grey metal oxidizes very quickly at room temperature and is also highly reactive. Misch-metal (cerium-lanthanum alloy with neodymium and praseodymium) is used in cigarette lighters when combined with iron and magnesium oxides. Cerium-oxide is considered one of the best glass polishers and is also used in polishing quartz, agate, opal etc.<sup>291</sup>

**Praseodymium**<sup>292</sup> (Pr) is a soft and malleable metal and a bit more resistant to corrosives than most of the REEs. Its oxide is one of the most refractory substances in the world. Together with other REEs it is applied in carbon arcs mainly used for studio lighting and projection in film industry.

**Neodymium**<sup>293</sup> (Nd) is another metal that is present in Misch-metal and is so up to 18%. It is a silvery lustrous element, which is among the more reactive REEs. It is used in colouring glass and is further applied in astronomical works, as well as in producing coherent light in lasers. It is also used in the production of so-called neodymium magnets, the strongest kind of permanent magnets.

**Promethium**<sup>294</sup> (Pm) is a radioactive element which requires careful handling. In the dark, its salts luminescence in green and blue colours. It is used for the conversion of light into electricity and has the potential to be used as a portable X-ray unit. It is also used as a power source for solar semiconductor batteries.

**Samarium**<sup>295</sup> (Sm) is a bright silver metal used, as some of the other lanthanides, in carbon arcs lightings for the motion picture industry. Its oxide is used as an infrared absorber in optical glasses as well as neutron absorber in nuclear reactors. Since the 1970's it has been used in the production of samarium-cobalt magnets, a permanent magnet. weaker than the neodymium one, but considered better for work in high-temperature environments<sup>296</sup>.

**Europium**<sup>297</sup> (Eu) is one of the most reactive REEs which quickly oxidizes. As its isotopes are good neutron absorbers, europium is used in nuclear control applications. It is also used as an activator in substances crucial for the production of TV tubes.

**Gadolinium**<sup>298</sup> (Gd) is known for its use in microwave applications as well as in phosphors used in TV tubes. This shiny silvery metal is also the element with the highest known thermal neutron capture cross-section.

**Terbium**<sup>299</sup> (Tb) is another gray metal soft enough to be cut with a knife. It is used in green phosphorus in TV tubes but its main application is in solid-state devices to dope calcium fluoride, calcium tungstate and strontium molybdate.

**Dysprosium**<sup>300</sup> (Dy) has a metallic lustre and a relatively low reactivity when compared to most of the lanthanides. However, even small impurities can severely affect its physical properties. It has potential to be used in nuclear applications and it has been applied, with vanadium, in laser production.

**Holmium**<sup>301</sup> (Ho) is a silvery metal that quickly oxidizes when exposed to high temperatures and a moist environment. There are not many uses known apart from the usual application of REEs in alloys.

**Erbium**<sup>302</sup> (Er) in air oxidizes slower than most REEs. As with some other metals from the group, its physical properties are sensitive to impurities. The main applications of Erbium are in the nuclear and metallurgical industry. When combined with vanadium, this metal tends to decrease the hardness of the alloy and make it more workable.

**Thulium**<sup>303</sup> (Tm) is a silver-gray metal of great softness. As it is relatively highly priced on the market, its practical applications are almost negligible but, just as Promethium, it is considered to be of potential use as a portable X-ray unit.

**Ytterbium**<sup>304</sup> (Yb) is a very soft, malleable and ductile element. Its main uses are in alloys (stainless steel) and lasers but one of its isotopes is also used as a radiation source for portable X-ray units when there is no electricity.

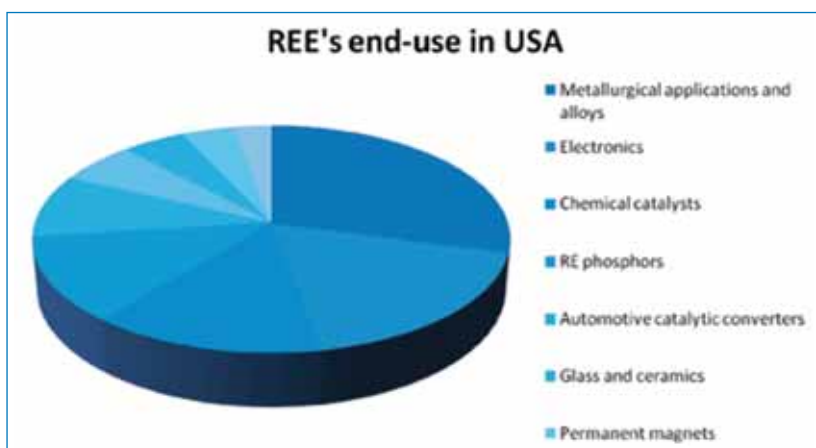
**Lutetium**<sup>305</sup> (Lu) is probably the most expensive of all REEs as it is present in only small amounts (usually accompanies Yttrium) and very difficult to extract. Its nuclides can be used as catalysts in various processes, including polymerization and hydrogenation.

### World production and reserves

RARE EARTH ELEMENTS						
Country	Mine Production (metric tonnes of rare-earth oxide)					Reserves
	2005	2006	2007	2008	2009	2009
China	119.000	119.000	120.000	120.000	120.000	36.000.000
India	2.700	2.700	2.700	2.700	2.700	3.100.000
Brazil	NA	730	650	650	650	48.000
Malaysia	750	200	380	380	380	30.000
World total	123.000	123.000	124.000	124.000	124.000	99.000.000

The primary production of REEs has been relatively steady, with Malaysia being the sole major producer registering a significant decline since 2005. Even though Malaysia figures among the major producers, its contribution to the global mine production of REEs is only 0.3%. China holds a full grasp over global primary REE production with as much as 96.7% in 2009, according to USGS data.

### KEY USES<sup>306</sup>

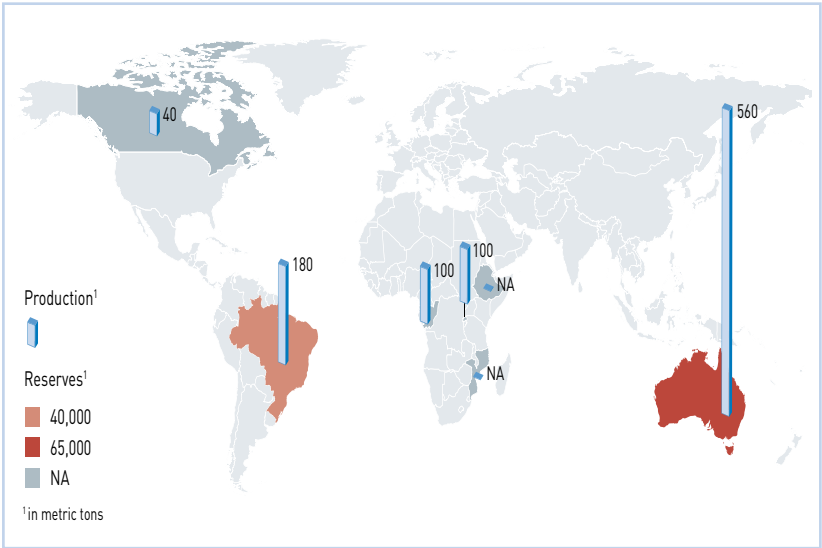


## RECYCLING

Although the role of REEs is rising in the field of green technology, thus increasing the demand of secondary produced REE metals, their recycling has been less than stellar. It appears, according to the United Nations Environment Program, that 'high-tech specialty metals' (REEs – especially neodymium as well as lithium and gallium which do not belong to the REE group) recycling accounts for around 1% while the rest is discarded.<sup>307</sup>



3.13 TANTALUM



Key Characteristics	TANTALUM <sup>308</sup>
Formula	Ta
Color	Gray
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Relatively ductile
Crystal	Cubic

This rare, conflict mineral<sup>309</sup> element can be found in as many as 54 minerals<sup>310</sup> and is compounded with niobium. However, only some minerals contain enough tantalum to make them exploitation worthy, such as microlite, wodginite, samarskite and euxenite. The most important sources of tantalum are minerals called tantalite and niobite. Although structurally these two are identical, the percentage of tantalum/niobium in their composition determines their name and primary use. Tantalum is also extracted as a by-product of ferro-niobium.

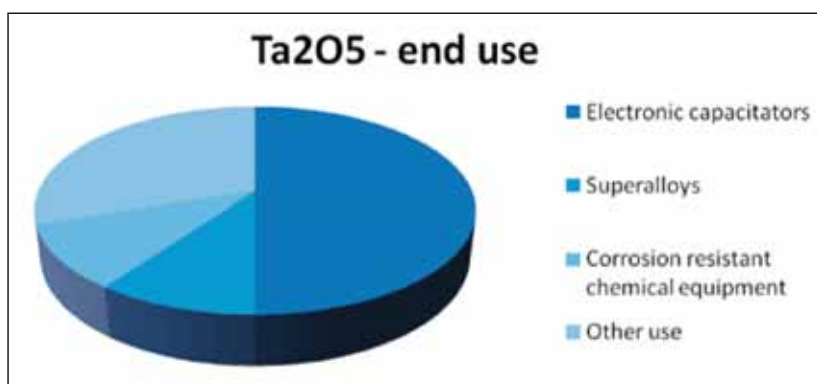
### World production and reserves

TANTALUM (in metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2009	2009
<b>Australia</b>	730	750	435	557	560	40.000	84.000
<b>Brazil</b>	250	250	180	180	180	65.000	90.000
<b>Rwanda</b>	40	62	42	100	100	NA	NA
<b>Congo</b>	25	NA	NA	100	100	NA	NA
<b>Canada</b>	70	68	45	40	40	NA	3.000
<b>Ethiopia</b>	45	70	77	NA	NA	NA	NA
<b>Mozambique</b>	81	70	NA	NA	NA	NA	NA
<b>World total:</b>	1.260	1.400	815	10170	1.160	110.000	180.000

The economic crisis seriously affected the tantalum industry. Due to price decreases, some of the biggest mines (such as Talison mines in Australia or Noventa's in Mozambique) were temporarily shut down, causing a significant decline in world production. This, together with an effective embargo on tantalum produced in conflict region of the DR Congo, makes it hard for the tantalum industry to assure supply in the coming years, particularly now that economies are recovering and demand is rising again.

## KEY USE

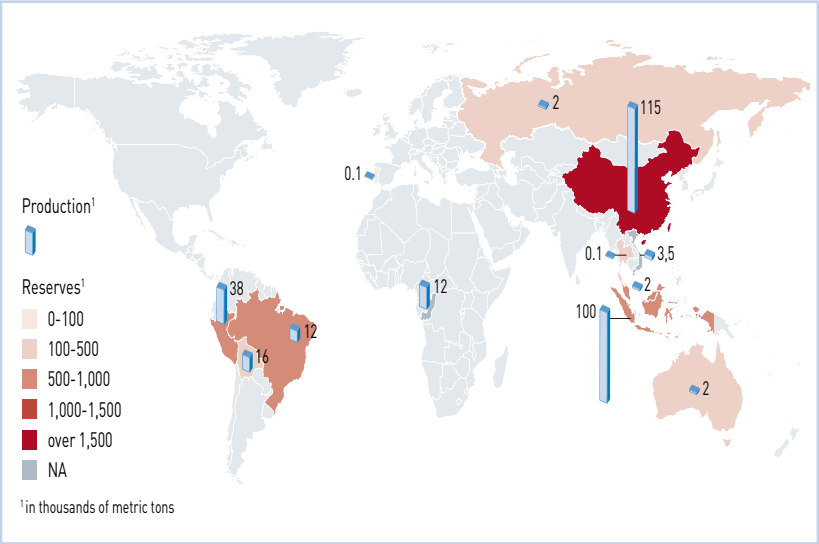
As one of the five major refractory metals, tantalum is being used in the electronic industry mainly for capacitors and high power resistors. Especially its heat resistance and high melting point make it very useful in manufacturing components for nuclear and chemical plants, missiles and aircraft.<sup>311</sup> Tantalum also has a wide use in the production of medical equipment as it is resistant to body fluids and causes no harm to the immune system.<sup>312</sup>



## RECYCLING

Tantalum gets recycled mainly from new scrap from electronic components and superalloy scrap. There are no released data on the amount of tantalum recycled in the world per year, but the recycling rate in USA in 1998 was estimated to be 35%. Certain estimations are claiming that the recycled tantalum participation in yearly consumption is approximately 20%.<sup>313</sup>

3.14 TIN



Key Characteristics	TIN <sup>314</sup>
Formula	Sn
Color	Tin-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Malleable
Crystal	Tetragonal

Tin is a relatively scarce metal and one of the earliest to be discovered and used. The main industrial source of this element is mineral cassiterite, although economically negligible amounts of Sn are being extracted from sulfides like stanite, cylindrite and teallite, to name only a few out of the 92 registered tin-bearing minerals.<sup>315</sup> It usually lays in placer sands and discrete grains.<sup>316</sup>

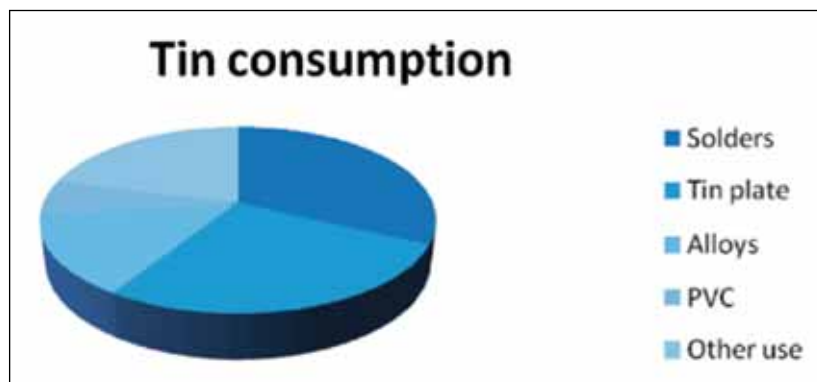
### World production and reserves

TIN (in metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2009	2009
China	120.000	125.000	135.000	110.000	115.000	1.700.000	3.500.000
Indonesia	80.000	90.000	102.000	96.000	100.000	800.000	900.000
Peru	42.100	38.000	39.000	39.000	38.000	710.000	1.000.000
Bolivia	18.700	18.000	16.000	17.000	16.000	450.000	900.000
Brazil	12.500	12.000	10.000	12.000	12.000	540.000	2.500.000
Congo	80	2.800	3.500	12.000	12.000	NA	NA
Vietnam	3.500	3.500	3.500	3.500	3.500	NA	NA
Australia	2.800	2.000	2.100	1.800	2.000	150.000	300.000
Malaysia	3.000	3.000	2.500	2.200	2.000	500.000	600.000
Russia	3.000	3.000	2.500	1.500	2.000	300.000	350.000
Portugal	200	200	100	100	100	70.000	80.000
Thailand	600	200	100	100	100	170.000	200.000
World total:	290.000	302.000	320.000	299.000	307.000	5.600.000	11.000.000

After a significant decline in 2008, global primary tin production is again on the rise according to the USGS estimations. Together the two most important producers, China and Indonesia, cover almost  $\frac{2}{3}$  of the global mine tin production.

### KEY USE <sup>317</sup>

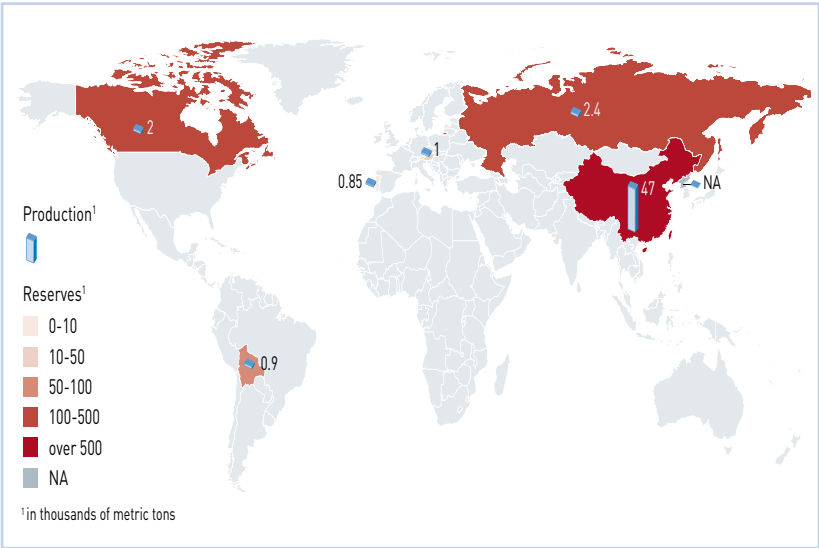
Due to its anti-corrosion character, tin is used to coat corrosive metals. Steel plated with tin is often used in the production of food preservation containers. Another usage of tin is in window-glass making. The procedure, which is called 'Pilkington process', entails floating molten hot glass over the molten tin making so-called 'floating glass' in order to create a perfectly flat surface.



## RECYCLING

According to the Recycling Guide, only one recycled tin can can save the amount of energy sufficient to power a TV for three hours.<sup>318</sup> Worldwide statistics are missing about the amounts of tin recycled per year. Available information is championing the US in tin recycling as it is creating roughly 12,000 tonnes of secondary tin in its 86 plants per year,<sup>319</sup> reaching 65.2% rate in recycling tin cans in 2008.<sup>320</sup>

3.15 TUNGSTEN



Key Characteristics	TUNGSTEN <sup>321</sup>
Formula	W
Color	Silvery-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Ductile
Crystal	Cubic

This metal, whose original name was wolfram, has the highest melting point of all metals (second highest for elements) and its density makes it one of the heaviest metals. It is also acclaimed for its high thermal and electrical conductivity. Among 36 IMA<sup>322</sup> registered minerals containing tungsten, the industrially most important ones are wolframite and scheelite.<sup>323</sup> Tungsten is also a by-product of processing porphyry copper<sup>324</sup> and molybdenum<sup>325</sup> deposits.

### World production and reserves

TUNGSTEN (in metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2009	2009
China	61.000	79.000	41.000	43.500	47.000	1.800.000	4.200.000
Russia	4.400	4.000	3.200	3.000	2.400	250.000	420.000
Canada	700	2.560	2.700	2.300	2.000	110.000	490.000
Austria	1.350	1.300	1.200	1.100	1.000	10.000	15.000
Bolivia	520	870	1.100	1.100	900	53.000	100.000
Portugal	820	780	850	850	850	4.200	62.000
North Korea	600	600	600	NA	NA	NA	35.000
World total:	70.100	90.800	54.500	55.900	58.000	2.800.000	6.300.000

After a sharp decline in tungsten mine production in 2007, there has been a slow but steady rise. The main reason of the significant decline in 2007 was a decrease in the estimated production of China (by almost 50%). China is by far the biggest primary producer of tin in the world, accounting for 81% of world production according to the 2009 USGS estimations.

### KEY USE

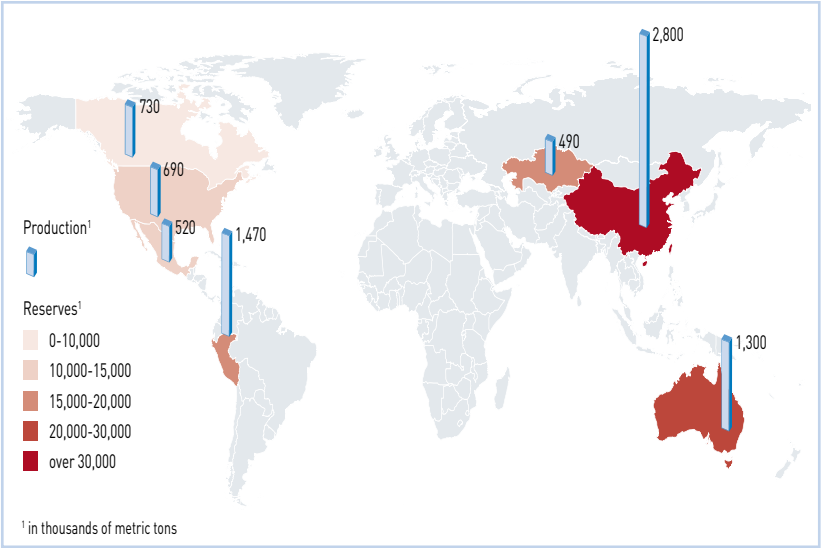
The International Tungsten Industry Association (ITIA) estimates that more than 60% of worldwide tungsten production is used to create hard metals.<sup>326</sup> Other uses include the production of steel and special alloys (e.g. in the production of diamond tools), lamps (since the beginning of the 20th century) as well as electronics, for which tungsten is used as practically the only material for electron emitters.



## RECYCLING

As much as 34% of the worldwide demand for tungsten is met by secondary production. The fact that the tungsten processing industry is capable of recycling almost all kinds of tungsten scrap makes this percentage less than impressive. In most countries recycled tungsten accounts for 30 to 40% of yearly consumption (37% in the US<sup>327</sup>).<sup>328</sup>

3.16 ZINC



Key Characteristics	ZINC <sup>329</sup>
Formula	Zn
Color	Bluish-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Brittle (malleable above 100°C)
Crystal	Hexagonal

Zinc is present with 70 parts per million (ppm) in the earth's crust. It mostly occurs in so-called sedex (sedimentary exhalative) and volcanogenic massive sulphide deposits (although there are as many as 5 major types of zinc ore deposits).<sup>330</sup> Among 218 minerals<sup>331</sup>, industrially the most important one is sphalerite, followed closely by smithsonite, hemimorphite and franklinite.<sup>332</sup> Zinc belongs to essential biological trace elements whose deficiency in the human organism can cause severe morbidities to growth and gonads, while overconsumption can cause mental lethargy and ataxia.<sup>333</sup> In small quantities zinc is produced as a by-product of melting sulphide ores.

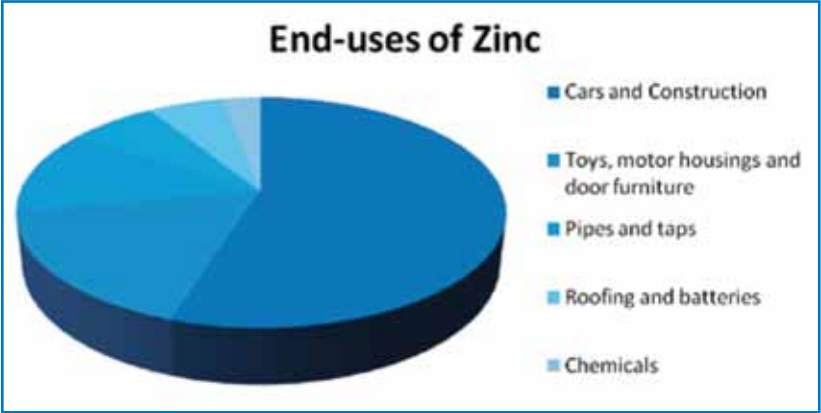
### World production and reserve

ZINC (in thousand of metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
	2005	2006	2007	2008	2009est.	2009	2009
China	2.450	2.600	2.900	3.200	2.800	33.000	92.000
Peru	1.200	1.200	1.440	1.600	1.470	19.000	23.000
Australia	1.330	1.380	1.520	1.480	1.300	21.000	100.000
Canada	755	710	620	750	730	8.000	30.000
USA	748	727	803	778	690	14.000	90.000
Mexico	470	480	430	400	520	14.000	25.000
Kazakhstan	400	400	390	460	490	17.000	35.000
World total:	9.800	10.000	10.900	11.600	11.100	200.000	480.000

After a 5% increase in global zinc mine production in 2008, the 2009 estimates show a decline again, mostly due to the decrease in production of China, a major contributor to the world production of zinc. The USGS estimated that two other major producers, Peru and Australia, would also experience a decline in production in 2009, but their projected decrease was relatively smaller than China's.

### KEY USE<sup>334</sup>

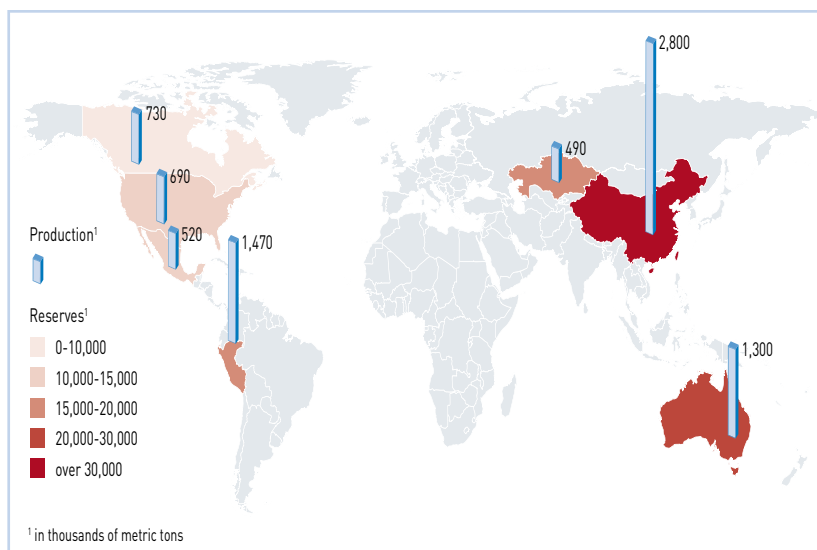
Zinc is mostly used as an anti-corrosion agent. Its relative reactivity makes it also useful in cathodic protection. The fact it has a good electrode potential makes zinc one of the important elements in batteries production. Zinc powder is used in alkaline batteries, while it is applied in anodes or as fuel in carbon-zinc ones.



**RECYCLING**

According to the International Lead & Zinc Study Group (ILZSG) recycled amounts of Zinc account for as much as 30% of total world consumption.<sup>335</sup> However, this number is not considered to be completely accurate as it includes only primary zinc scrap.<sup>336</sup>

### 3.17 ZIRCONIUM



Key Characteristics	ZIRCONIUM <sup>337</sup>
Formula	Zr
Color	Grayish-white
Streak	Shiny
Transparency	Opaque
Luster	Metallic
Tenacity	Ductile and malleable
Crystal	Hexagonal

This element with close visual likeness to diamond can never be found in its native state but always compounded, most often with hafnium, from which separation is difficult. Out of 114 registered minerals containing zirconium<sup>338</sup>, only one is considered to be an economically important resource, namely zirconium silicate, also known as zircon. Others include baddeleyite and kosnarite. Zircon is usually a side-product of titanium and tin ore processing and in its commercial grade it contains 1-3 % of hafnium.<sup>339</sup>

### World production and reserves

ZIRCONIUM (thousand metric tonnes)							
Country:	Mine Production					Reserves	Reserve base
						(million metric tonnes)	
	2005	2006	2007	2008	2009est.	2009	2009
Australia	445	491	605	550	510	25	35
South Africa	305	398	400	400	395	14	14
China	17	170	180	140	140	0.5	3.7
Indonesia	NA	NA	NA	42	42	NA	NA
Ukraine	35	35	35	35	35	4.0	6.0
India	20	21	29	30	30	3.4	3.8
Brazil	35	26	31	27	27	2.2	4.6
World total:	880	1.180	1.430	1.280	1.230	56	77

The global mine production of zirconium between 2005 and 2009 reached a peak in 2007, increasing with as much as 450 thousand metric tonnes. However, since 2008 production shows a slight yet constant decline. Australia, being the largest producer according to USGS estimations, was covering 41.5% of global zirconium mine production followed at some distance by South Africa and China.

### KEY USE

Due to its poor ability to absorb neutrons, zirconium has an important use in nuclear reactors in the claddings of fuel rods. It is also used in the production of hard metal alloys and consequently in the production of surgical instruments, as well as cutting tools that require extraordinary hardness.<sup>340</sup> With its exceptional anti-corrosive qualities, zirconium is also used in the chemical industry, especially in highly corrosive environments.<sup>341</sup> It is also used in the production of high-strength ceramics, mostly for medical applications as prostheses.<sup>342</sup>

### RECYCLING

Zirconium is mainly recovered from primary scrap. There are not many companies recycling Zirconium, but those who do, recycle it mainly from Zirconium and Zirconium alloys scrap generated from metal production. The usual process involves melting the scrap and then separating it. Zirconium needs to be separated from hafnium, for example, if it is to be used in nuclear fuel appliances cladding.<sup>343</sup>





## 4 GLOSSARY

AIST	National Institute of Advanced Industrial Science and Technology
BERR	Department for Business, Enterprise and Regulatory Reform
BGS	British Geological Survey
CBI	Confederation of British Industry
CNAS	Center for a New American Century
CSIS	Center for Strategic and International Studies
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
EU	European Union
GDP	Gross Domestic Product
IAGS	Institute for the Analysis of Global Security
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JOGMEC	Japan Oil, Gas and Metal National Corporation
MERI/J	Metal Economics Research Institute
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MMAJ	Metal Mining Agency of Japan
MOU	Memorandum of Understanding
MRP	Minerals Reconnaissance Program
MSP	Mineral Policy Statement
NEXI	Nippon Export and Investment Insurance
NRC	National Research Council
ODA	Official Development Assistance
OPEC	Organization of the Petroleum Exporting Countries
PGMs	Platinum Group Metals
REEs	Rare Earth Element
RESTART	Rare Earths Supply-Chain Technology and Resources Transformation
R&D	Research and Development



## REFERENCES

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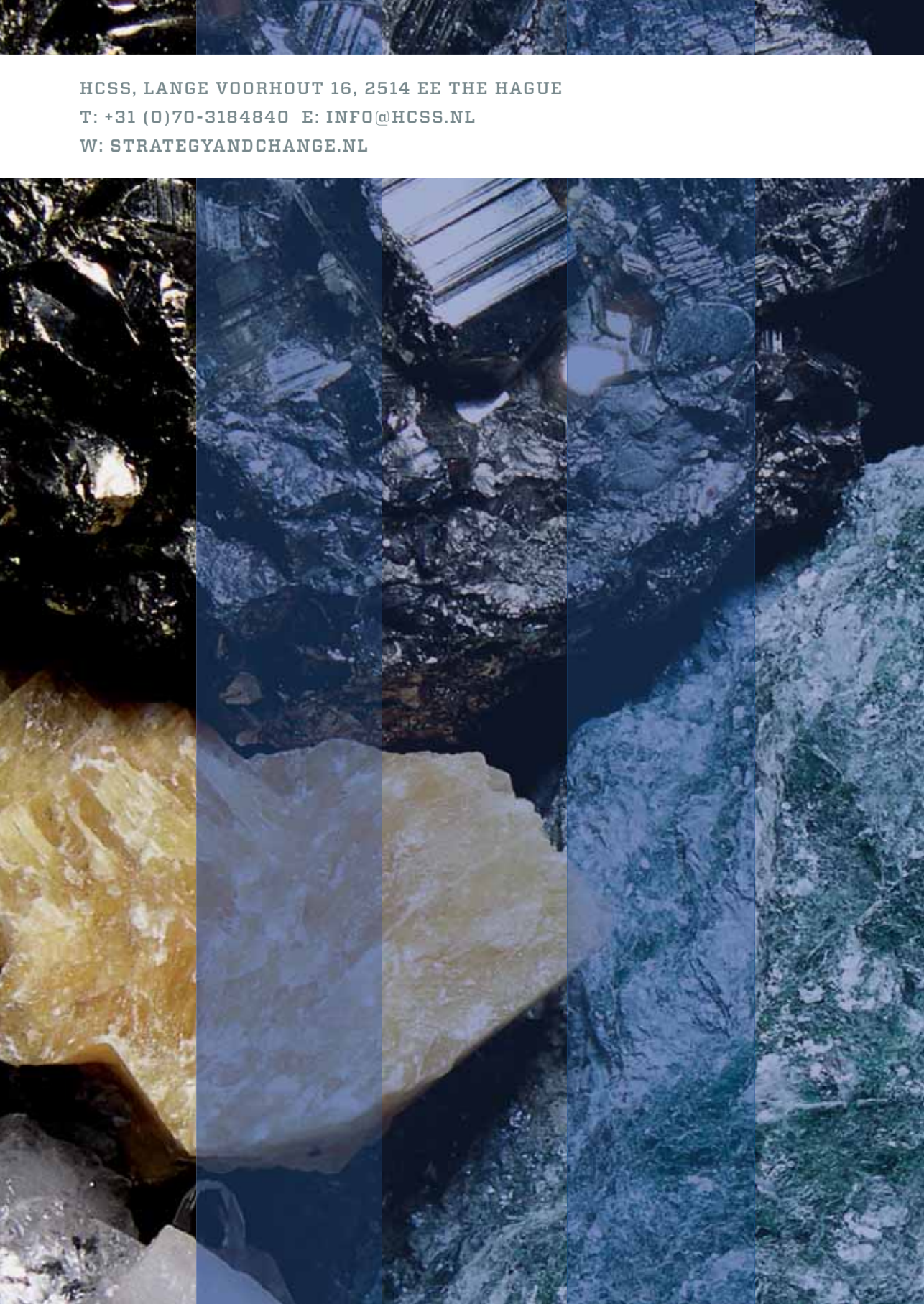
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