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Strategically important metals

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Additional written evidence

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The Science and Technology Committee

The Science and Technology Committee is appointed by the House of Commons to examine the expenditure, administration and policy of the Government Office for Science and associated public bodies.

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Written evidence

Written evidence submitted by G R Chapman (SIM 01)

I worked for 30 years in the British Geological Survey, chiefly on the DTI-funded Minerals Intelligence Programme. I advised the DTI on, *inter alia*, the strategic stockpile (1983–1996) and was latterly an accredited NATO expert advising that organization's Industrial Policy Committee on raw materials supply.

General Remarks

— It is important that the Committee should give sufficient weight to the economic and geopolitical aspects of these issues and not be too engrossed in scientific and technological aspects.

— The methodology for selecting the metals to be included should be carefully considered and also transparent. Relevant factors differ markedly between different metals.

— The Committee is right to state that "the exact impact of such a decline [in availability] on UK high technology industries is unclear". Assessing this impact is likely to be the most difficult part of the task.

Comments on the Committee's Terms of Reference

1. *Is there a global shortfall etc*.

1.1 Historically, global shortfalls have led to upward price movements that in turn lead to increased production. However in the case of minerals and metals new production capacity can take years to bring on stream. Any decision about new capacity is governed by perceptions about the duration of the supply problem.

1.2 For industrial consumers the price of some metals is far less important than reliability of supply.

1.3 Obviously consumers prefer to pay the lowest negotiable prices for raw materials but diversification of supply with a consequent price "penalty" may be thought worthwhile in order to ensure supply.

2. *How vulnerable is the UK to etc*.

2.1 The USA has kept a stockpile of strategic/critical minerals for several decades, although it is now reduced in scope. It was very costly to maintain.

2.2 HM Government formerly had a small stockpile of strategic minerals. It was set up by the DTI in 1983 and its abolition was then announced in November 1984. In fact the last sales were not made until 1996. The materials concerned were never disclosed by the DTI but in its issue of 30th July 1985 the commercial journal "Metal Bulletin" published estimates for tonnages of certain metals and alloys in the stockpile. The list comprised forms of chromium, cobalt, manganese and vanadium.

2.3 You should also be aware of the House of Lords (1982) Strategic Minerals. Report of the Select Committee on the European Communities. HMSO, London. Although produced twenty-eight years ago, it may be useful to look at the methodology used to reach its conclusions. Essentially this report defined "strategic minerals" on the basis of the twin components of "criticality" and "vulnerability". Criticality was based on the view that the mineral was essential to the national economy. Vulnerability was based on the proportion of domestic consumption, which was imported and the number of overseas supply sources contributing to that supply. The fewer and more unstable the sources the more vulnerable the supply.

3. *How desirable, easy and cost-effective to recover and recycle etc*.

3.1 I am not aware that there is any difference between "recover" and "recycle" The former is tending to be used by commercial entities as a fashionable catchword.

4. *Are there substitutes for those metals etc.*

4.1 Substitution lies under similar constraints as investment in new capacity. It may be technically and scientifically feasible, but commercially impossible in the short and medium terms for reasons to do with contractual specifications

5. *What opportunities are there to work internationally etc.*

5.1 I comment on this question simply to point out that it uses the word "substituting" in the vulgar sense used by football commentators. This word does not mean "replacing"—which is the meaning intended in your document. In football it doesn't matter. In materials science it does.

G R Chapman PhD FGS CGeol

December 2010

Written evidence submitted by Nicholas Morley (SIM 02)

1. *Is there a global shortfall in the supply and availability of strategically important metals essential to the production of advanced technology in the UK?*

1.1 In absolute terms, there is no scarcity of metals. Copper is the only element where this subject has been seriously debated, but even in this case the resource optimists appear to have the most convincing arguments at present.

1.2 At the start of the Industrial Revolution many metals were mined in the same country in which they were consumed (although of course international trade in certain metals such as tin goes back thousands of years). There is an increasing, long term trend of metals being mined in different countries from which they are consumed. Poor governance in some of these countries, limited commitment to free markets, increased demand for metal resources due to increased population and wealth, and use of certain speciality metals in applications important for the "Green Economy" are all factors in the increased interest in strategic metals

1.3 China is a special case where there is a combination of large speciality metal reserves, a potentially huge internal market for products made from these metals, and an explicit economic development strategy to supply high value added products rather than commodity metals or their ores.

1.4 New mines typically take 7–10 years to develop. Therefore there will a lag between the imposition of short term measures such as quotas and the introduction of new supplies. There is also the complication that many speciality metals are by-products or co-products from the manufacture of other metals. Hence the output of these metals are influenced by the demand for metals in other applications and material cycles.

1.5 Arguably, UK and Western companies have paid too little recent attention to raw material risk which has allowed dominant positions that China in particular now has in some metals. So to a extent the problems in rare earths and some other metals is caused by what might now be seen in hindsight as a naïve belief in the permanency of free markets for their raw materials and an unwillingness to pay a premium in order to reduce raw material supply risk.

1.6 How quotas play out in terms of availability of metals can be complex. There may be no shortage of metals but rather increasing competition between different applications for strategic metals, with their inclusion in products where price sensitivity is the least important. There will be increasing competitive advantage for companies located inside China (in the case of rare earths) for both price and availability. This has to be set against the risk of locating factories in China that will for example be dependent on supplies of rare earths from mines with generally poor environmental records and where the other issues of doing business in China such as intellectual property protection may be significant.

1.7 In the medium to long term we believe that a greater number of mines in different countries will be developed and the problem will correct itself. In the short to medium term there may well be supply issues with certain metals and consequent price volatility.

2. *How vulnerable is the UK to a potential decline or restriction in the supply of strategically important metals? What should the government be doing to safeguard against this and to ensure supplies are produced ethically?*

2.1 The impact on the UK is likely to be less than in countries such as Japan and Germany, due to its smaller high technology manufacturing base. There will be some direct impacts, but we believe that mostly the impacts will be indirect through suppliers in other countries. An example is the defence supply chain, which is rightly concerned about restrictions of supply based on geopolitical issues, and where countries such as the USA are far more exercised on this issue than the UK. We are not aware of studies to define the significance of the risk to the UK apart from a current Defra project on resource risks, which might have addressed this issue and which will report shortly. Hence it is difficult to comment on the degree of vulnerability. However energy security issues in our opinion could have a far greater direct impact on the UK than material security issues.

2.2 There are four responses possible to material security issues:

Negotiate privileged access.

Stockpile.

Substitute.

Resource efficiency measures such as minimise use, extend product lifetime and recycle.

Possible stockpiling at an EU level, similar to what occurs in Japan has been proposed, but is generally not preferred in free market economies such as the UK. Also the timescale over which it could operate (typically months rather than years) is not sufficiently long to address some of the speciality metal supply issues.

2.3 If supplier countries are members of the WTO (such as China), then mechanisms do exist to encourage the removal of restrictions on free trade. Although to comment on these is beyond our area of competence, this would seem an obvious arena in which the UK Government could act.

2.4 The Government, through the Technology Strategy Board, could provide innovation funding to develop substitutes, although the timescales on commercialising these is likely to be of the same order as opening new mines as sources of supply.

2.5 A mix of resource efficiency measures could be implemented more quickly and would be a useful role for government and would contribute to security of supply and is highly likely to contribute to overall greenhouse gas reduction. Likely measures include a combination of design for remanufacturing/recycling, minimisation of use through use of existing substitutes, product longevity strategies such as remanufacturing, voluntary closed loop recovery systems and recycling technologies. It is important that resource efficiency is not seen as simply recycling. Allied with this would be policy change measures at an EU level to move away from simple percentage recycling rate for ELVs and WEEE to one that takes greater account of strategic metals occurring in automotives and in electrical and electronic goods. However one proviso is that in fast growing areas such as rare earths for high strength magnets, the growth of the market and longevity of the products is such that even high levels of recycling of discarded materials will only provide a modest proportion of current supply.

2.6 As regards ethical supply, this is difficult when metal producing countries are increasingly separated from the consuming countries and often have poor environmental and social governance. We propose that an increased use of standards, ecolabels and sustainable public procurement will help to communicate the message that metals sold in the UK need to be "clean". Thus a business case can be made to producer organisations as well as appealing to ethical and environmental motivations. We declare an interest as a contractor helping to deliver the EU Ecolabel within the UK.

3. *How desirable, easy and cost-effective is it to recover and recycle metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

3.1 Speciality metals typically have high embodied energy, and where manufactured in countries with carbon-intensive energy systems, high embodied carbon. They also have large volumes of resources associated with their extraction and refining. Hence techniques to increase their resource efficient use are recommended.

3.2 Resource efficiency solutions should not be thought of solely in terms of recycling, although this is the first approach that tends to be suggested by metal-orientated companies because of their familiarity with the secondary metals sector. Since many speciality metals are only used in small quantities and their applications can be dissipative, recycling is often very difficult, as evidenced by their often low recycling rates despite high prices. Hence alternative strategies such as extension of the product lifetime through remanufacturing, refurbishment or reuse may be a good strategy before materials recycling. When recycling must take place, strategies such as product take-back, design for disassembly will be increasingly required to obtain these relatively small amounts of speciality metals.

3.3 Policy changes may be required to make recovery cost-effective eg changes to the WEEE Directive and ELV Directive to target specific metals rather than an overall percentage mass recycling target.

3.4 Given the relatively low tonnages of many of these metals, recycling may only make economic sense with one or two plants within the whole of Europe. If exported outside of Europe, recycling may or may not be carried out in an environmentally and socially responsible way. If the materials are defined as hazardous waste, then controls should be possible under the Basel Convention.

3.5 Oakdene Hollins is currently undertaking a project funded by the European Pathway to Zero Waste Project that is assessing the potential for recovery and recycling of the fourteen metals identified by the EU Raw Materials Initiative as "critical". This will include infrastructure and collection requirements (particularly in the SE of England), carbon impacts of recycling, the demand/supply balance and international best practice.

4. *Are there substitutes for those metals that are in decline (sic) in technological products manufactured in the UK? How can these substitutes be more widely applied?*

4.1 In the case of rare earth elements magnets (a major application for rare earths), some substitution is possible in some applications. However the rare earth magnets based on neodymium iron boron have been optimised over a period of around 25 years and no substitutes of equivalent performance exist. Generally, substitution across the strategic metals is often difficult, since they are often expensive and economic factors have encouraged their substitution with cheaper elements if possible. An extreme case is the Platinum Group metals, where there has been substantial effort to reduce its use in catalytic applications.

5. *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

5.1 A number of criticality studies have been or are currently being undertaken and are likely to identify a research agenda with a great deal of commonality between the US, Japan and Europe

5.2 Some work on substitution of critical metals is already being encouraged in the Framework 7 European research programme.

5.3 A number of networking events have been undertaken on this issue, for example the recent EU-US workshop on rare earth elements and other critical materials for a clean energy future held at MIT on 3 December. The outputs from this meeting of researchers should be available shortly.

5.4 Given the likely minimum economic scale of recycling operations, the links to European legislation, and the visibility of the security issues at a European level, the best level of collaboration for the UK would appear to be at an EU level.

6. Background

Oakdene Hollins researches and consults on sustainable products and services. We also run the Centre for Remanufacturing and Reuse, the only European centre of its kind, which promotes those activities with products when they can be shown to environmentally beneficial. We are part of UK Ecolabel Delivery, which is concerned with the EU Ecolabel scheme.

We have carried out the following projects on the issues of strategic metals and materials security:

— In 2008 our report "Material Security: ensuring resource availability for the UK economy" was published by the Resource Efficiency Knowledge Transfer Network (now the Environmental Sustainability KTN). This concluded that there were not absolute scarcities of metals, but that the increasing environmental impact of mining, extraction and purification were likely to lead to limits in production before absolute scarcity became significant.

— In early 2010 we completed a study on the likely availability of the rare earth elements for the low carbon economy, including the possibilities of substitution and recycling, for the Department for Transport and for the Department for Business, Innovation and Skills. We concluded that there were likely to be short to medium term shortages of certain key rare earth elements for high strength magnets, particularly if China continued its reduction of export quotas. Since that time, the announcement of a greater than expected reduction in Chinese quotas, with consequent price increases, and the use of rare earths supply in geopolitical disputes with Japan, has been widely reported in the press.

— For the Institute for Energy, a Joint Research Centre of the European Commission we are currently researching critical metals in the materials supply chains of six of the energy generation sectors that form part of the European SET Plan for achieving low carbon energy generation targets. These sectors are nuclear, wind, photovoltaics, smart grid, carbon capture and storage (CCS), and biofuels. This report will be completed in early 2011.

This response is submitted by Nicholas Morley, Director of Sustainable Innovation, and does not represent company policy.

Nicholas Morley

14 December 2010

Written evidence submitted by University of Strathclyde and University of Oxford (SIM 04)

THE MINERALOGICAL LIMITATIONS OF LOW CARBON ENERGY:
RESEARCH TOWARDS A TRULY SUSTAINABLE ENERGY FUTURE

Executive Summary

Although the conclusions of the Club of Rome report "The Limits to Growth" have now been largely discredited, the introduction of new technologies to support renewable energy, such as fuel cells, batteries, PV etc will place strain on certain strategically important materials. One example is the provision of platinum group metals for fuel cells. **We recommend the formation of a research cluster whose objectives will be to identify crucial gaps in materials supply and to propose new research directions, such as alternative materials or effective recycling that will make renewable energy truly sustainable**. The UK is in a global competition for these resources and as things stand will not be able to proceed to a carbon free economy. These problems will not simply disappear and it is our recommendation that an academically based experts committee be formed to examine the reliance of clean energy technologies on strategically important minerals. It is fundamentally important to develop new research lines in this area.

Introduction

The arguments promoting the use of clean, renewable sources of energy such as wind, marine, solar and bio-derived to replace fossil fuel sources are so well known that it is hardly necessary to discuss them here. The environmental, economic and security arguments have sparked a global effort to develop energy supply chains based on these sources. Although the debate over whether nuclear energy is a sustainable energy still rages, for our purposes it is regarded as a low-carbon technology that will have an important part to play in reducing carbon emissions over the medium and long-term. Consequently, it is given an equal weighting here.

Given the fact that there is more than enough wind, marine, bio and solar energy to satisfy societal needs the question "Is renewable energy sustainable?" may seem paradoxical. However, as will be demonstrated here, current technological developments in renewable energy rely on mineral sources that are most definitely *not* sustainable: A complete reassessment needs to be made of the deployment of such technologies and indeed, the development of certain technologies may be completely abandoned.

All of this is set against an increasing global requirement for energy in all of the OECD, BRIC-bloc (Brazil, Russia, India, China) and developing countries.

Renewable energy sources have created new challenges but perhaps the hardest to deal with is their intermittent or unpredictable nature, or indeed, both. Perhaps the next greatest challenge is to provide energy for transport. The solution here is to develop efficient energy storage systems. For convenience, technologies of importance here are categorised as hydrogen or electron based. The hydrogen route consists of hydrogen production (such as electrolysis), storage and conversion (such as PEM fuel cells). The non-hydrogen route relies on devises such as batteries, supercapacitors, superconducting magnetic energy storage and flywheels.

Alongside this is the need to develop efficient methods for energy collection, distribution and conversion. Examples of energy collection are wind turbines, photovoltaic devices. New technologies for energy transmission include superconducting cables. High temperature fuel cell designs such as solid oxide and molten carbonate based devices are being developed for the efficient conversion of bio-derived power.

The above list is not exhaustive but represents some of the most heavily researched areas of renewable energy. Each of them relies to some a greater or lesser extent on increasingly scarce mineral resources. Their potential global deployment would therefore perturb current markets to a corresponding extent that needs to be analysed in considerable detail.

Before this, it is important to set a reasonable global context for future energy requirements. According to Energy Information Authority figures, annual global energy utilisation is about 500 Quadrillion Btu. Although energy consumption has fallen in the EU, China showed an increase of energy consumption of 7.7% in 2007 and globally energy consumption is likely to rise at an annual rate of 2–3%. The time frame considered here is fifty years; by which time other energy technologies (such a nuclear fusion, which also creates mineralogical problems which are considered here) may well dominate.

Estimation of Minerals Reserves

Much of the data used here is based on the United States Geological Survey (USGS) database[1]. The USGS make a clear distinction between the ideas of "Reserve" and Reserve Base". They also list the annual production rate for most minerals. From these two values a Reserve to Production (R/P) ratio can be calculated with the unit of years. R/P ratios are commonly used for fossil fuel reserves and give an estimation of the lifetime of reserves if used at a particular rate.

The USGS definition of Reserve is relatively straightforward and is defined as "A concentration of naturally occurring solid, liquid or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity is currently or potentially feasible". Whilst massively useful in itself this paper deals with technologies that will create new demands on mineral resources, a situation which will certainly distort commodities markets and require new minerals deposits to be developed. Consequently, the USGS Reserve Base figures are of more use here. Understandably, the definition is a little less clearly defined but is best illustrated by the following key phrase "The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves) and some of those reserves that are subeconomic (subeconomic reserves)". Therefore, if unprecedented demands were to be made on a particular mineral, this is a more conservative, and realistic figure. The USGS also give information about the current utilisation of different minerals, how much is recycled, possible alternative materials and a global distribution of resources.

As an example consider Boron, the base of a possible hydrogen storage material, Lithium Borohydride. The current global reserve (as B_2O_3) is estimated at 170 10^6 Tonnes whereas the Reserve Base is estimated at 410 10^6 Tonnes. The current rate of production of Boron (in all forms) is estimated at 4.3 10^6 Tonnes yr^{-1}, although the figure for the USA is withheld for commercial reasons. The principal use of Boron is for glasses and ceramics (72%) for which there is no industrial substitute. A negligible amount of Boron is recycled.

The above illustrates a number of features to be discussed. Firstly, the (static) R/P ratio based on Reserves is less than 40 yr but the R/P ratio based on the Reserve Base is almost 100 yr. The fact that a negligible amount of Boron is recycled leads to the concept of "minerals entropy" in which relatively concentrated forms of Boron are eventually distributed globally leading to an almost irrecoverable loss. Clearly, unless Boron is recycled then it should not be regarded as a long-term sustainable resource.

The issue here however, goes well beyond these considerations and asks the question as to what would happen if Boron were to act on a large scale as a material for the storage of hydrogen. In fact, there is physically not enough boron in the world to satisfy the demand for large-scale hydrogen storage and it is questionable whether research in this subject is worthwhile from a commercial point of view. As will be seen, te situation is equally critical for a wide variety of raw materials.

Although the famous report from the Club of Rome "The Limits to Growth" (1972) is largely discredited, we feel that the issues raised will become a reality within the next forty years, unless research is taken into developing alternative forms of renewable generation, storage and conversion starting immediately. The research cluster proposed here will commence and coordinate this activity within the UK and in close cooperation with the country in which these issues will be even more important, China.

The Need to Develop New Energy Technologies

We have identified the technologies most at risk from the availability of strategic minerals and the following have agreed to participate in such a cluster:

— Professor Peter Hall (Strathclyde)—energy storage.

— Professor Peter Edwards FRS (Oxford)—hydrogen.

— Professor Xiao Guo (UCL)—Chinese links, hydrogen and biofuel cells.

— Professor George Smith FRS (Oxford)—nuclear fission and fusion materials.

— Professor Professor Stuart J C Irvine (Glyndŵr University, OpTIC Technium)—PV.

— Professor Peter Bruce FRS (St Andrews)—Li batteries.

— Professor Stephen Skinner (Imperial)—high temperature fuel cells.

— Professor Keith Scott (Newcastle)—low temperature fuel cells.

— Professor Nick Hanley (Stirling)—resource economics.

Each of the cluster members are well connected to the energy community in the UK and collectively the group has a track record of participation on governmental committees and supplying evidence to parliamentary committees. This is essential to our mission of influencing both future research directions and energy policy.

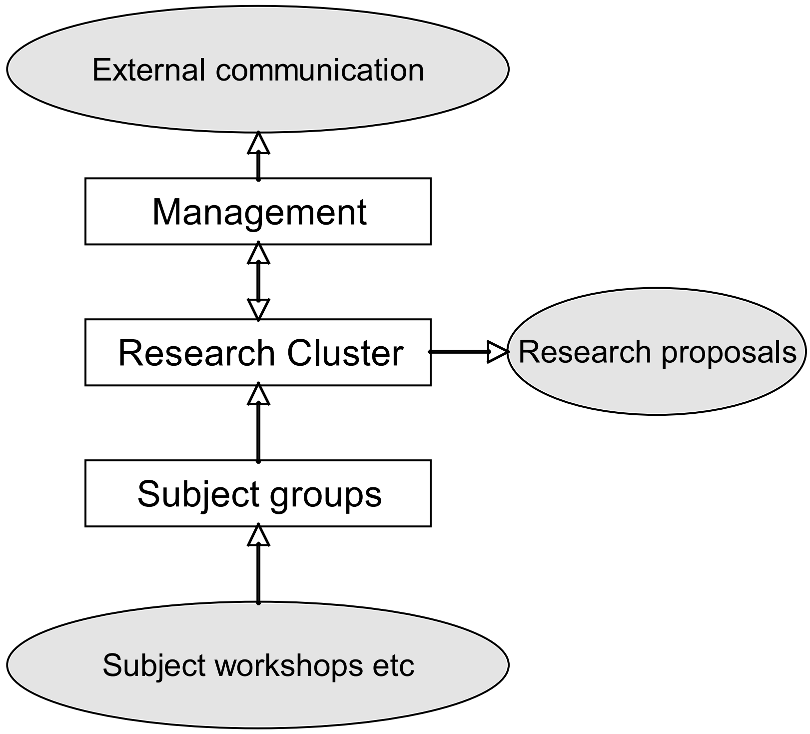
The main activities of the subject will be small meetings; national and international study visits and UK workshops. There will be differences in the activities of the subject groups to enable specific information to be gathered and assessed, for example to determine information about specific minerals directly from mining companies etc.

The subject groups will feed information into the cluster for biannual meetings. The main function of the cluster will be to produce two high profile reports. The first produced by the end of the fourth quarter will be a comprehensive overview on the supply problems of renewable energy to be published in a high impact journal such as Science. Additionally, the cluster will formulate and support joint research proposals to EPSRC and ESRC. The final high impact report will be a review of the progress made by the cluster in pointing the way to a truly sustainable energy future.

The main functions of the management team will be external communications, publicity, cluster meeting organisation and final report assembly. Since the work of the cluster is of long term consequence and will need monitoring beyond the scope of this call, the cluster have agreed to meet on a regular basis beyond three years and that this will be funded out of individual research contracts or by a further proposal to EPSRC, Royal Society etc of necessary.

Work Programme

The work will be divided into two broad (overlapping) phases: problem identification and the development of radical, sustainable alternatives to current paradigms. In general terms, problem identification will consist of establishing the relationship between current developing technologies and the availability of strategic materials in terms of the likely global requirement. This is by no means a trivial task, requiring forward thinking and interactions with other consortium members, especially regarding the geochemical and economic aspects. One key objective of the first phase will be to write new research proposals to strengthen the applied geochemical and resource economic aspects of the consortium. The second phase is equally challenging and will develop new research directions to ameliorate or avoid the materials supply problems



(i) Energy Storage (Peter Hall). Energy storage is also considered in the hydrogen and battery subject groups and this subject is mainly concerned with redox flow batteries and **superconducting magnetic energy storage.** These are two research groups that are under represented in the UK although superconducting technologies were mentioned in the recent MAT-UK report on transmission and distribution. Research needs to be conducted into the use and availability of a number of materials such as Yttrium, Strontium, Barium and Bismuth amongst others. As the class of high temperature superconductors increases annually, it is necessary to produce a summary report relating the scientific progress to metals availability. In the field of **redox batteries** large amounts of materials are needed to produce the large devices needed for storing grid energy. Therefore it is important to relate the different redox cycles eg vanadium, cerium and zinc based systems to materials availability and safety:

(ii) Links with China (Xiao Guo) China's rapid and continued rise in economic and technological stances largely influences the global resource and climate issues. Close engagements with key scientists, funding bodies and policy makers in China are important to sustain a clean energy economy. While priorities may vary, close bilateral discussions and exchanges are beneficial to scientific and technological planning, resource management and long-term collaborations. In this aspect of the Cluster, we aim to foster UK-China interactions by the following strategies: 1) Organisation of bilateral forums on "Clean Energy and Resource Implications for Sustainable Low-Carbon Growth", with early involvement and co-sponsorships from National Natural Science Foundation of China and Chinese Academies of Sciences and Social Sciences, linking to the newly formed National Energy Bureau / Commission; 2) Establishing links with a multidisciplinary group of influential Chinese scientists in social, economic and natural sciences by exchange visits and focussed discussions, eg via the internet; 3) Identifying the overall challenges for resources and low-carbon energy technologies and specific areas for joint research projects with co-funding opportunities from funding agencies, eg joint projects from the Ministry of Science and Technology and EU Framework Seven.; and 4) Creating a sustainable UK-China network in "Sustainable low-carbon economy—tackling the Mineralogical Limitations and Challenges", which may be extended to other international links, as the Cluster expands over time.

(iii) Nuclear (George Smith) The materials resource issues involved in nuclear power generation are highly complex, and there are many uncertainties involved in making forward projections. There are two main technologies to consider: nuclear fission and nuclear fusion. These involve rather different issues. **Nuclear fission** technology is relatively mature, and the main resource issue is the long-term availability of fuel materials. With the upsurge of global demand for new nuclear build, important questions arise about the future availability of adequate supplies of uranium minerals. In some countries (eg India), there is an upsurge of interest in alternative fuel cycles, for example based on thorium. Fuel reprocessing will become of increasing importance, and the use of fast reactors to "breed" additional fuel supplies will need to be re-visited. Elsewhere in the nuclear fission sector, there is increasing emphasis on safety, reliability and efficiency, extension of safe operating lifetimes, and reduction of the need for routine maintenance and inspection. New designs are emerging for high-temperature gas-cooled reactors, modular reactors, and hybrid electricity and hydrogen-generating reactor systems. It is too early to say whether these trends will put any real pressures on natural resources, but it will be necessary to keep the whole of this field under constant review. One example from current research will indicate the kind of issues that can arise. It is becoming clear that the stress corrosion cracking resistance of the stainless steels used in reactor primary cooling systems can be markedly improved by additions of certain platinum group metals (PGMs). Whilst this may improve the reliability and durability of nuclear plant, such a technology change would put additional pressure upon an already stretched PGM resource sector. In the case of **nuclear fusion**, the materials challenges are far from clear, because the field is still at an early stage of development, and the final selection of preferred materials for commercial-scale fusion energy power systems will not have to be made for one or perhaps two decades. However, some key issues can already be identified. One concerns the lithium blanket, used to breed tritium for use in the reactor. It seems likely that large-scale use of lithium in that application could put some strain on global resources for this material. Also, if superconducting magnet technology is employed, the sheer scale of the magnet engineering required could put pressure on the supply chain for the very high quality niobium alloys (or equivalents) that will be required. Finally, and perhaps most importantly of all, there is a pressing need to develop new alloys that can withstand unprecedented levels of heat and neutron irradiation without suffering rapid degradation of mechanical properties, or becoming excessively radioactive (and thereby generating a new range of waste storage and / or disposal issues). A broad spectrum of materials is under consideration, ranging from oxide-dispersion strengthened steels (involving rare earth additions), to exotic metals such as vanadium. In a number of cases, large-scale deployment of such materials could lead to severe shorter-term pressure on global production capacity, and perhaps ultimately to significant impact upon global resources.

(iv) PV (Laurie Peter). Photovoltaic cells based on monocrystalline silicon will be replaced at least in part by cheaper thin film solar cells as the cost of **PV** power is driven downwards towards a level that can compete with power generation from fossil fuels. Several technologies are in the running—the most promising for the short term being based on cadmium telluride and copper indium diselenide as absorber materials. In the longer term concerns about the toxicity of cadmium and the rapidly increasing price of indium raise issues of sustainability. In an effort to address these concerns, Professor Peter's group in Bath is working on low cost dye-sensitized solar cells as well as on new sustainable inorganic absorber materials for thin film solar cells. Dye-sensitized solar cells can be fabricated using low cost titanium dioxide and small amounts of sensitizer dyes. This technology is already being used by G24i in a newly established plant in Wales, and the Bath group is collaborating with other UK research centres and Corus Coatings to develop dye cells on metal substrates for deployment in roofing areas. Work on inorganic thin film solar cells continues as part of the recently renewed PV21 SUPERGEN programme. Sustainability is a central platform of the renewal programme, and inorganic materials identified in Bath as potential candidates to replace materials such as copper indium (gallium) diselenide include the very promising compound copper zinc tin sulfide (CZTS), in which the costly indium and gallium are replaced by equal amounts of zinc and tin. CZTS cells with world-leading efficiencies have already been fabricated in collaboration with colleagues at Northumbria. Other materials that will be explored include copper bismuth sulfide, which has promising properties. The search for new materials will be underpinned by a detailed computational exploration of emerging and new materials using the UK Teraflop supercomputer (HPCx) at Daresbury

(v) Batteries (Peter Bruce). There is expected to be a large and continuous increase in the demand for **Li based batteries** over the next twenty years for transport and grid applications. The dominant technology at present consists of a negative electrode formed from carbon (usually graphite), a positive electrode based on $LiCoO_2$ and an organic electrolyte based $LiPF_6$ dissolved in a mixture of alkylcarbonates as the electrolyte. Cobalt has been the dominant cathode material in rechargeable lithium batteries since their introduction. The mining of cobalt is economically viable in only a few locations worldwide and these are politically and economically unstable. In recent years the price of cobalt has increased almost tenfold with major implications for the lithium-ion battery industry. The limited availability of Co on the planet means that it is unviable to develop larger scale lithium batteries based on Co. Considering cost and abundance, Mn and Fe are the most attractive elements with which to form lithium transition oxides suitable as cathodes in future rechargeable lithium batteries. However even these metals have seen significant increases in cost and demand over recent years. For example, between 2006 and 2008 the demand for Fe ores increased by some 40% so even these materials, regarded presently as abundant and cheap, may not continue to be so in the new industrial landscape in which India and China are major players.[1] Concerning the anode, already the performance limitations of graphite have resulted in the replacement of this material by metal alloys, such as the introduction recently by Sony of a metal alloy anode based on Sn and Co. In addition to the comments made about cobalt above, the supplies of Sn may be exhausted within 20 years. Again we see that even the new generation lithium battery technologies can only have a limited lifetime because of resource implications. Although there is no metallic lithium in a lithium-ion battery, lithium is a major component. There are widely different predictions concerning the planetary resources of lithium (lithium carbonate). A Recent report by R. K. Evans[2] suggests that there are abundant lithium resources corresponding to 28.5 million tonnes of lithium, equivalent to sufficient lithium carbonate for 1,775 years of supply. In contrast, another report from Meridian International Research[3] estimate around four million tonnes of which around two million tonnes of chemical grade lithium carbonate are likely to be available by 2015. These vastly different predictions demonstrate that it is crucial to undertake a rigorous examination of the resource implications for future lithium-ion technology. Such considerations drive towards the development of new lithium-ion battery materials from waste biomass or crops. This could have radical implications for the direction of research in the field, signalling a move away from inorganic materials to organic based cathodes and anodes. Given the critical nature of this technology in addressing global warming it is vital that a group of scientists, engineers and geoscientists, knowledgeable on lithium batteries, their materials requirements and mineral resources, examine the significance of raw materials and tension them against the drivers of cost and performance.

(vi) High temperature fuel cells (Stephen Skinner) **Solid oxide fuel cells** (SOFCs) are a technology area that has been in development for many years and has now reached a point of maturity where viable large-scale commercialisation is imminent. Indeed in the UK, for example, utilities such as Centrica have entered partnerships with fuel cell developers to deploy 30,000 units over the next five years and in the US, it is anticipated that annual spending on fuel cells will reach $975 million by 2012, growing by 600% from current values. The high temperature SOFCs are based on the development of ceramic oxides (functional oxides) that overcome some of the concerns with low temperature fuel cells that rely on high Pt contents. However bulk oxide development and deployment of SOFCs raises concerns over the availability, and security of supply, of many of the materials currently considered as state-of-the-art. These include rare earth stabilised zirconia, and Gd-doped CeO_2 amongst others. To address these concerns the group at Imperial College is investigating a number of approaches: development of new oxide and related materials with greater ionic conduction, implementation of nano-fabrication to reduce materials requirements and enhance properties, investigation of complementary technologies (eg proton conductors). Much of this work is performed in conjunction with the SUPERGEN fuel cell consortium, and is focussed on the durability of fuel cell components. These programmes are concerned with the long term viability of materials solutions and involve the interaction with materials simulation experts to identify potential new components. We are also actively involved in developing epitaxial thin film technology and deposited heterostructures with groups in Europe and the US. Further complementing our activities are linkages with groups in Beijing focusing on new technologies including $BaCoO_3$ cathodes and $SrTiO_3$ anodes.

(vii) **Hydrogen storage** (Peter Edwards). Hydrogen storage is one of the most complex subjects in the area of renewable energy. A wide variety of systems have been evaluated for potential development and it is still not clear which system will come to dominate. As has been noted earlier, the sever limitation in supply of certain materials such as boron may exclude their future development and indeed an analysis of the availability of strategic materials will help clarify research directions in this area. The most promising systems are based around light metals such as Li and Mg but to be effective they need to be doped with a catalyst to reduce hydriding temperature or to improve kinetics. This can be either a transition metal or a Pt group metal. Therefore, one obvious research direction would be to relate the loading of these additional metals to their availability and to estimate their impact on global production rates and recycling.

(viii) **Low temperature fuel cells** (Keith Scott). Fuel cells and electrolysers for hydrogen production are prime examples of technologies where resource availability will have a major impact. Notably combating the resource limitation of Pt. Achieved by researching alternative materials with alternative cell technology or operating conditions. The issues for both technologies are similar and can be tackled using similar strategies. For **Hydrogen PEMFC** technology there is interest in the application of alternative electrocatalysts to Pt such as Raney nickel (Ag may be suitable) and inter-cell connectors based on stainless steel, such as Ni. **High temperature PEMFCs** can increase conductivity and improve electrode kinetics, which can provide the opportunity for alternative electrocatalysts. Alternatives are based on palladium; but again resource limitation may exist. Research is also taking place to further reduce the PT content and alternatives based on non-precious metals such as W may be possible. For the cathodes, there is large interest in Pd and Au based catalysts but alternative non-precious metal catalysts should be investigated. In the field of **electrolysers** hydrogen production by water electrolysis is based on one of two technologies; alkaline electrolytes and solid polymer electrolytes (SPE). Currently the dominant (lower cost) route to hydrogen is alkaline electrolysis. The use of a solid polymer electrolyte (SPE) in water electrolysis enables hydrogen production from pure (demineralised) water and electricity. Proton exchange membrane (PEM) water electrolysis systems offer advantages over traditional technologies; greater energy efficiency, higher production rates (per unit electrode area), and more compact design. Like proton exchange membrane (PEM) fuel cells; catalysts used are based on precious metals: Pt for the cathode and a mixture of Ru; Ir; Ti (with possibly Sn; Pt) oxides for the anode. The anode catalyst cannot be supported on carbon as it oxidises at the potential for oxygen generation. Thus catalysts are unsupported typically deposited onto the membrane. Anode electrocatalyst connectors need to based on an inert metal such as Ti or Ta. Alkaline (hydroxide conducting) membrane electrolysers; combine the advantages of the PEM electrolyser and the alkaline electrolyte electrolyser. The application of alternative electrocatalysts to Pt such as raney nickel (is Ag sustainable). High temperature PEM electrolysers can increase conductivity and improve electrode kinetics which can provide the opportunity for alternative electrocatalysts.

(ix) Resource economics (Nick Hanley). Mineralogical limits to renewable energy technologies pose interesting questions for economists in terms of market failure and institution design, and are an example of a supply-side constraint on a development path. Currently, knowledge is very limited on the extent to which market forces will smooth the transition towards a low-carbon economy, in the presence of government interventions such as tradeable carbon credits and green certificates for renewable electricity. Possible causes of market failure with respect to supply-side constraints include (i) public good aspects of R&D into alternative sources of inputs and alternative technologies (ii) information asymmetries (iii) externalities connected with the supply chain and (iv) private sector discount rates being higher than the social rate of discount. In addition, the distributional impacts of supply-side issues may lead the government to intervene in market adjustments on non-efficiency grounds. Three main activities are envisaged. The first is the organisation of an international workshop on the economics of renewable energy, focussing on supply-side factors and innovative policy solutions to problems identified. This will bring together economists from across Europe and the US with an interest in renewable energy, and will result in publication of a workshop proceedings. We will also seek to publish this collection as an edited book, for example the the Routledge series on "Explorations in Environmental Economics", for which NDH is the series editor. A smaller group of economists will then take the most promising ideas contained within the workshop proceedings, and work them up into a series of policy proposals, which can be analysed in a second workshop which will draw on non-economist members of the cluster and its stakeholder community. This will lead to the publication of a second report containing a finalised set of policy proposals from the cluster on the issue of instrument design and supply-side constraints to renewable energy development. This report will then be launched at a stakeholder conference to be held towards the end of the cluster's award period.

References

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Written evidence submitted by Aerospace and Defence Knowledge Transfer Network, Materials and Structures National Technical Committee (NTC) (SIM 05)

Disclaimer

The Materials and Structures National Technical Committee (NTC) membership is drawn from industry, academics, government agencies and independent experts with activities or an interest in the UK Aerospace and Defence Industries. The views and judgments expressed in this review reflect the consensus reached by the NTC and do not necessarily reflect the views of the organizations to which its membership is affiliated. While every care has been taken in compiling this report the Materials and Structures NTC and its members cannot be held responsible for any errors, omissions or subsequent use of this information.

1. Introduction

This report aims to review the factors which are likely to impact on the provision and sustainability of the main strategic metal elements within the UK aerospace and defence supply chain, and to consider these within the context of the business environment risks, strategic risks, financial and operational risks faced by UK industry. This is a high level strategic consideration of the issues rather than a detailed analysis at product level.

2. Strategic Metals for The Aerospace and Defence Industries

The global economic recession of the last two years has impacted the production, selling price and market forecasts for all metal commodities. Whilst generally consistent, there are differences in the extent to which individual markets have been affected, and the time scales over which they are projected to recover. It is thus worth noting these effects separately for each metal.

Metals perceived to be of the highest concern for the aerospace and defence sector are Cobalt, Hafnium, Platinum and Rhenium.

2.1 *Chromium*

South Africa and Kazakhstan account for about 62% of global chromite production, which is equivalent to approximately 70% of global ferrochrome production. Chromium-containing products include ferrochromium, chromium chemicals, and metallic chromium. Ferrochrome dominates the market. The major chromium-metal producing countries in the world are France, Russia, China, and the United Kingdom for aluminothermic chromium metal and the United States and Russia for electrolytic chromium metal. The aluminothermic process dominates global production, about 95%.

Security of Supply

There are no substitutes for chromium metal in stainless steel and super-alloy production. With the restriction environmental restrictions on hexavalent chromium alternatives to chromium plating for surface protection are beginning to become available. Given South Africa's dominance in chromite production, any disruption there can impact significantly on global availability and price. In 2007–08, electricity disruptions also impacted on global ferrochrome and metallic chromium. This supply constraint pushed prices up more than 100% over their average value in the preceding 12 months. Kazakhstan, like South Africa, is ranked "borderline" on the Failed States index, and in the poorest 15% of countries performing according to the Policy Potential index. Both scores suggest a moderate-to-high degree of risk associated with on-going production from both countries, however, global reserves suggest there is enough economically recoverable chromite for many years to come.

2.2 *Cobalt*

Cobalt is a common alloying addition in steels, magnetic, wear resistant and high strength alloy systems eg superalloys. The Democratic Republic of Congo dominates global production, followed by Canada, Zambia, Australia and Russia. China is the world's leading producer of refined cobalt, and much of its production is from cobalt-rich ore and partially refined cobalt imported from the Democratic Republic of Congo (this reflects Chinese investment in African minerals more generally).

Security of Supply

Cobalt is mostly produced as a co-product of other base metals, notably copper and nickel. Cobalt demand has focused attention on the reprocessing of copper tailings to recover cobalt. Waste processing costs are a variable, but this has not stopped considerable international joint-ventures in this area, to help stabilize global supply. The lower production figures in other countries, such as Australia, reflect the lower grade of cobalt in run-of-mine ores. The ability to ramp up cobalt production in countries other than the Democratic Republic of Congo is dependent on market demand for the primary coproducts. The Democratic Republic of Congo "Failed State" index position is a worry (it is the 5th most critical country), and there has been evidence of political interference, corruption, smuggling and other criminal activity associated with cobalt concentrate production in that country. Several internationally funded projects have been cancelled as part of a government review. Cobalt and its compounds are used in a wide variety of applications, including several emerging ones driven by technology innovation. The diversity and growth of other applications could put additional pressure on the metal's use.

2.3 *Hafnium*

World primary production figures for hafnium are not available. It is produced as a coproduct of zirconium from the titanium rich mineral sands industry. The hafnium to zirconium ratio is about 1:50, and physical separation is difficult. However, it is possible to get an indicative picture of hafnium production from the US Geological Surveys for zirconium, coupled to an indication of hafnium reserves. This results in an estimated global production to be of the order of 100 metric tonnes. Australia and South Africa dominate production. Both industries are well-developed, with the necessary infrastructures in place..

Security of Supply

The nuclear industry dominates hafnium usage (56%)with the aerospace industry using a further 33%. With the anticipated growth in nuclear technology for power generation, there will be an increased demand for hafnium. Also, the semi-conductor industry is looking to hafnium as a (partial) substitute for silicon. This new demand, coupled to that for capacitors, will place additional pressure on supply. Given that hafnium is a minor co-product in the mineral sands industry, additional supply capacity will be slow to materialize, due to industry inertia.

Using the 1:50 metric, there is no shortage of hafnium reserves into the medium term.

2.4 *Lithium*

Chile is the leading lithium producer, followed by Argentina. Both countries recover the lithium from brine pools. In the United States lithium is recovered from brine pools in Nevada. Nearly half the world's known reserves are located in Bolivia. In 2009 Bolivia began negotiating with Japanese, French, and Korean firms to begin extraction. China may emerge as a significant producer of brine-source lithium carbonate around 2010. There is potential production of up to 55,000 tonnes per year if projects in Qinghai province and Tibet proceed. In the aeerospace industry the major uses of lithium are as an alloying addition for lightwieght aluminium strauctural alloys and in Li-ion batteries.

Security of Supply

There is currently no shortage of lithium and it is thought that world supply can comfortably meet demand. However this will change isf significant numbers of electric and hybrid cars start to be manufactured. The total amount of potentially available lithium worldwide has been estimated at 15 million tonnes, of which 6.8 million tonnes is currently economically recoverable.Using the figures of 6.8 million tonnes of Lithium and 400g of Lithium per kWh this gives a total maximum lithium battery capacity of 17 billion kWh which is enough for approximately 320 million electric cars with a 53kWh battery. This typeof demand may lead to sugnificant shortage of supply for structural metallic application s and for batteries in other industries.

2.5 *Nickel*

The biggest reserve of nickel are in Australia, which has a well-developed mining infrastructure, and minerals investments are relatively low-risk; however, production in Canada, Indonesia and Russia now exceeded that in Australia. Other significant reserves include South Africa and Cuba. There was minimal fall-off in production in 2008 over the previous year which suggests that the demand for nickel has bottomed-out, and demand will likely increase as the global economy recovers. Roskill Metals and Minerals Reports, based on projections for stainless steel growth, predict a 3–5% increase in demand for nickel beyond 2010.

The global market is dominated by six countries; The USA, China, Japan, Germany, Taiwan and South Korea. Of these, only China mines some of its primary ore. Close to 70% of the global flow goes to stainless steel manufacture, and 60% of discarded nickel is recycled within the nickel and stainless steel industries. The total dissipative loss is 14% of the discarded amount. This global picture suggests that nickel management over its life cycle is reasonably good (certainly compared to other metal commodities such as aluminium and copper).

Security of Supply

Whilst there is some potential to reduce nickel content of certain austenitic stainless steel applications in construction, it is unclear whether similar reductions could be achieved in more specialist areas, e.g. superalloys, without invoking supply constraints for other specialty metals such as titanium or chromium. According to the Failed States Index Australia belongs to the subset of "most stable" countries. Canada is described as "stable". Russia, Indonesia and Cuba are all described as "in danger", and South Africa is "borderline". This picture does not change when the policy potential index is invoked. Here, Indonesia, Russia and South Africa are all in the bottom quartile. Cuba is not ranked. The situation is compounded by other performance measures. South Africa provides a good example of some of these. Firstly, its nickel deposits are associated with the largest global reserves of platinum group metals, and it is the refining of the latter which drives the production of nickel, copper and cobalt. Secondly, the country's electricity supply network is at breaking point, and significant power outages have affected its mining operations in the last two years. This is exacerbated by conflicting policies and contradictory infrastructure resource plans. All of these factors contribute to the significant uncertainty which clouds minerals' investments in this country, and could impact negatively on its metal output—not just for nickel and platinum.

Overall the supply of nickel seems secure.

2.6 *Platinum*

Global supply of platinum is dominated by South Africa's. The primary ore is a nickel, copper, cobalt deposit, with a platinum group metal concentration of less than 5 ppm platinum and palladium. Major uses are in coatings for corrosion protection, catalysis, electrical contacts, electrodes and thermocouples.

Security of Supply

South Africa's problems with infrastructure provision (electricity and water), its relatively poor track record on mine safety, and political interference in mining operations, have, in the past, all contributed to price instabilities and supply problems. These pose the greatest threat to security of supply.

2.7 *Rare Earths*

Global supply of rare earths is dominated by China with over 98.9% of world production (>124,000 tonnes as oxide per annum). Significant deposits exist in Russia and the United States but at the moment these are not being worked. Smaller amounts are produced by India, South Africa and Malaysia. Rare earths are essential alloying additions to a variety of products from metallurgical additions to bulk alloys (eg cerium to Mg alloys and steels, samarium and neodymium in magnets and scandium to aluminium alloys) to phosphors and as addition s to glasses and ceramics The major uses of rare earths in the defence and aerospace sector are in computer hard disc drives, batteries, superconductors, lasers, sensors, inertia guidance systems etc. Some of the more exotic aero-engine blade alloys also contain small amounts of rare earth additions.

Security of Supply

The rare earth market is complicated because of the large number of elements and their broad range of applications for which demand fluctuates over time, largely as a result of technological developments. The market has a history of abrupt change, eg in the 1960 samarium was the dominant rare earth due to the demand for samarium-cobalt magnets, by the 1980s this position had changed and a major demand was for neodymium in magnets has developed alongside the demand for samarium.

Rare earth elements are not openly traded commodities and there are low levels of transparency and a general lack of market information. However, prices are very volatile and spikes in excess of 300% have been observed.

Historically the balance of supply and demand has been fairly stable. However in the last three years the market has changed from a position of oversupply to one of demand shortages Also significant growth is forecast in most sectors of rare earth consumption, particularly for metals and magnets which have predict growth rates of 10–15 and 15–20 % respectively.

Although China's rare earth production has been increasing in recent years it has been reducing export quotas due to increasing domestic demand. China has also increased tariffs on the rare earths and their oxides. Closure of operations due to environmental concerns has further reduced supply. There is thus growing concern about the security of supply from China.

Spurred by increased demand and concern over China's effective control of the rare earth market, searches for alternative sources in Australia, Brazil, Canada, South Africa and the United States are ongoing. Mines in these countries were closed when China undercut world prices in the 1990s, and it will take a few years to restart production. One example is the Mountain Pass mine in California, which is projected to reopen in 2011. Other significant sites under development outside of China include the Nolans Project in Central Australia, the remote Hoidas Lake project in northern Canada, and the Mount Weld project in Australia. The Hoidas Lake project has the potential to supply about 10% of the $1 billion of REE consumption that occurs in North America every year

Currently it is thought that of the rare earths of interest here only the neodymium supply may not meet demand.

2.8 *Rhenium*

Rhenium is associated with the production of molybdenum, and principally from copper porphyry deposits. Its production is dominated by countries with significant copper mining and processing activity. Chile dominates primary production, with close to 50%, in 2008, followed by Kazakhstan and the USA. Close to 80% of production is consumed in super alloy manufacture for use predominantly in gas turbines. Its use in catalysts is a growing market.

Security of Supply

Price volatility is the hallmark of the rhenium market. Based on a 10 year market average price (1997–2007), this range is close to 30-fold. The peak in 2008 was a symptom of continued demand for super-alloys, as well as problems being faced by one of the world's largest producers of refined metal. This volatility has challenged the aerospace industry to review its dependence on rhenium. The main issue with security of supply is the fact that the availability of rhenium concentrate is dependent on copper and molybdenum refining. The price of these primary metals dictates the dynamics of rhenium production.

2.9 *Ruthenium*

Global production figures for ruthenium are not available. However, production / reserve figures can be estimated based on those of platinum as ruthenium is present in platimun group metal ores at less than 1 ppm. Annual production is estimated at 30 metric tons. South Africa dominates the global supply and all insights from the platinum analysis and apply equally to ruthenium. Dominant uses are in electrical applications and hard-drives. Use in superalloys has been contemplated but the economics are prohibitive. The demand in such an application would rapidly exceed supply, leading to extreme price sensitivity to any perceived application.

2.10 *Tantalum*

Global supply of tantalum is dominated by Australia, followed by Brazil. Major uses are as an alloying addition to steels and superalloys and for capacitors.

Security of Supply

Events over the last 12 months have precipitated a crisis in the tantalum supply industry, despite reduced demand. The world's largest supplier in Australia, which is singly responsible for more than 30% of global supply (Australia delivers about 70% of global production), has suspended its mining operations due to an expected continued decline in demand. This, coupled to a run down of global inventories, and growing calls to embargo purchases from central and east Africa, means that the tantalum industry faces considerable uncertainty until at least 2012.

2.11 *Titanium*

The world production of titanium metal is based in the US, Russia, Japan, China, UK, France, Kazakhstan, Ukraine, and Germany and overall world production is predicted to exceed demand for the foreseeable future. The major application is in metallic structural systems for land, sea and air applications.

Security of Supply

Although supply is predicted to exceed demand globally there is an increasing demand on the high quality aerospace grades that UK aerospace and defence industry relies on. The UK titanium industry is focused on these grades, but there is growing dependence on Russia to supply these materials, based on their large cold war manufacturing facilities. To date this has not caused any problems, but with the political and economic uncertainty this position may change quite suddenly. China is also expanding its capabilities and is investing heavily in production and research and development facilities, mainly for domestic use but with an increasing world-wide presence.

2.12 *Vanadium*

Vanadium is mined mostly in China South Africa and , Russia. In 2007 these three countries mined more than 95 % of the 58,600 tonnes of produced vanadium, with China dominating productiion. Approximately 85% of vanadium produced is used as ferrovanadium or as a alloying addition in steels and titanium alloys.

Security of Supply

World production of vanadium grew by more than 7% per annum from 2003 to 2008. Initially, production increases were met by taking up spare capacity at existing operations but from 2006, capacity had to be increased to meet demand. Most of this expansion, however, was also at existing mines and plants, most notably in China. In the next few years additional supply could come from re-opening the mine and plant at Windimurra, a new mine and plant in Brazil, further expansion of slag output in Sichuan as well as an increase in by-product output from uranium processing in the USA and South Africa.

Overall the supply of vanadium seems secure.

3. Substitution

All the elements discussed above cannot easily be substituted in the aerospace and defence industries. The unique properties they engender in materials cannot be replicated by either using less of them or by replacing them with other elements. It is thus essential to UK industry that we have a long term, stable source of these materials. An example would be Rhenium and Ruthenium as alloying additions in the highest performing single crystal turbine blade alloys for gas turbines. In this application despite conferring unique property advantages, because of the economic constraints use has not been made of Ruthenium additions and lower Rhenium content alloys are being developed.

4. Recycling

It is difficult to discuss recycling for a diverse group of metals like this as their use, and hence recycling challenge, differs depending upon the metal. They can however be grouped into two main types:

(1) Bulk materials—eg steels, titanium alloys, nickel alloys, magnets etc. In these cases the materials are widely used and in a bulk form. Recycling is thus relatively straightforward as removal, collection and recycling are organised on a large scale and the industry actively supports these activities today.

(2) Minor /trace additions, eg low alloying additions and trace amounts. These are more difficult to deal with as the strategic metals are widely dispersed, both physically and chemically, used in small amounts and are difficult to identify. In these cases it is often uneconomic to attempt recovery and they are lost to the production chain. Only where an element has an unusually high value or is particularly scare is this attempted and even then this is often restricted to within a company. It is in this area that most work is now going with attempts to identify viable recycling methods and routes. This is being done on a global scale by the industry as this is a common global problem to all users.

A recently developed source of rare earths is discarded electronics and other wastes that have significant rare earth components. New advances in recycling technology have made extraction of rare earths from these materials more feasible, and recycling plants are currently operating in Japan, where there is an estimated 300,000 tons of rare earths stored in unused electronics.

5. Mitigating Actions

The uses of the majority of these elements are specific to particularly industries and hence the responsibility for taking mitigating actions lies with the major players in these sectors. In many cases these actions are underway.

Aerospace and Defence Knowledge Transfer Network
Materials and Structures National Technical Committee (NTC)

16 December 2010

Written evidence submitted by Wolf Minerals Ltd (SIM 06)

1.0 Introduction

1.0 This submission to the Select Committee is made by Wolf Minerals Ltd. Wolf Minerals is based in Perth, Western Australia and listed on the Australian stock exchange. The principle business of the Company is the development of deposits of tungsten. The Company has assets in Australia, but the principle asset is the Hemerdon tungsten deposit in Devon UK. This submission deals specifically with tungsten but sets that within a broad framework of where the UK government may need to take action on all strategic or critical metal minerals.

1.2 The EU Commission has identified (June 2010) tungsten as being one of the 14 most critical mineral raw materials essential to the European economy but which are under threat of restricted availability.

The Hemerdon Deposit

1.3 The Hemerdon deposit has been described (British Geological Survey, in press) as "one of the largest tungsten resources in the western world", with a total ore tonneage of 218.53 million tonnes containing 318,800 tonnes of tungsten. The deposit is currently being taken forward with the prospect of the first production of concentrate in 2013. The operation will involve the development of the first modern open pit metal mine in the UK, provide 200 skilled jobs and revenue of $100 million per annum. The open pit will extend to an oval shape, circa 850 metres by 540 metres and to a depth of 200 metres. Primary plant on site will produce concentrate for onward shipping to a processing plant in Europe. There is currently no tungsten processing plant in the UK. Around 4,500 tones of concentrate, equivalent to approximately 2,900 tonnes of tungsten metal, will be produced each year, sufficient to contribute significantly to meeting UK demand.

1.4 The Hemerdon deposit has a valid commenced planning permission which is currently being upgraded by Devon County Council through a Modification Order, with the full support of Wolf Minerals. As part of that process Wolf Minerals has offered a Unilateral Undertaking to provide further amenity and environmental works. Other regulatory permits are being pursued.

1.5 The Hemerdon deposit lies between Dartmoor and Plymouth and outside any major environmental protection areas. The development of this mine confirms the high prospectivity of parts of the UK for metals and the ability of the external amenity and environmental impacts to be managed in a manner which prevents nuisance or harm. There has been a perception that metal mining is neither economically viable nor environmentally acceptable in our crowded and protected country. The actuality, as evidenced by Hemerdon, is that the metal mineral resources in the UK can be utilised for our economic benefit, without harm to amenity or the environment.

1.6 There is also a perception that metal mineral resources in the UK are fully known and that there is therefore very limited opportunity to provide metal from within the UK. This perception, alongside that of "peak metal" (the concept that global reserves are fully known and will run out in a few decades), is not correct. In most of the prospective areas within the UK the mineral potential is unknown at economic depths and there are indications of substantial targets.

1.7 Given that the planning and regulatory systems in the UK are both rigorous but fair, developing our own resources not only provides income, employment and security of supply for industry but also complies with sustainability, makes economic sense, and reduces the pressure on weaker regulatory regimes, environments and societies elsewhere in the world. Developing our own resources both enables the UK to minimise the off-shoring of environmental and health costs to other nations, but also ensures that the UK can negotiate trade agreements from a strong position.

1.8 Wolf Minerals is not a tungsten processor. The processing of tungsten is a specialist and cost intensive operation. However, the scale of annual production from Hemerdon might provide an incentive for a processor to build a new plant in the UK taking production from Hemerdon, supplemented by small arisings from other deposits which could then become viable, and scrap for recycling from the UK and Western Europe. Such a plant would need to meet the rigorous UK regulatory requirements and would therefore ensure that recycling is done in a cost effective, safe and ethical manner.

2.0 Tungsten

Tungsten

2.1 Tungsten constitutes only 0.00013% of the Earth's crust. Economic minerals containing tungsten are primarily Wolframite and Scheelite. Tungsten has the highest melting point (3422°C) of all elements except carbon but also has excellent high temperature mechanical properties and the lowest expansion coefficient of all metals. With its density of 19.25 g/cm^3, tungsten is also among the heaviest metals. Tungsten has the lowest vapour pressure of all metals, very high moduli of compression and elasticity, very high thermal creep resistance and high thermal and electrical conductivity.

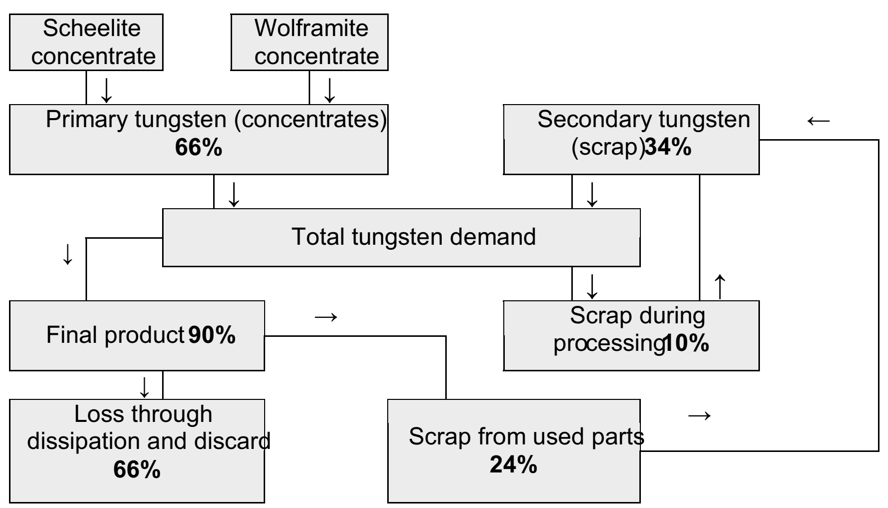
Reserves

2.2 The United States Geological Survey estimates global tungsten reserves (proven, workable deposits and excluding Hemerdon) at 2.8Mt. China accounts for over 60% of world reserves. Other countries with reserves of tungsten, typically a tenth of the reserves of China, include Canada, the CIS and the USA. CIS reserves are probably considerably overstated. Other limited reserves are located in Asia, with smaller deposits in Europe, Latin America and Australia.

Production, Demand and Shortfall

2.3 Primary global tungsten production increased steadily from 35,650t in 1998 to an estimated 66,000t in 2010, of which China produced over 80%. Demand for tungsten tends to correlate closely with economic output, as tungsten demand in one year reflects growth in GDP from the previous year. Primary extracted tungsten meets about 66% of total demand. The remaining 34% is supplied through recycling (see Figure 1 below).

Figure 1 : Supply of tungsten



Source: ITIA

2.4 Given the historical relationship between tungsten demand and GDP, future tungsten consumption will closely follow GDP growth at both the global and regional levels. For the period 2010 to 2015, demand at the world level is estimated (Roskill) to grow annually by 6–7%, with global demand reaching almost 90,000t by 2015. However, existing production capacity and production capacity from all current new projects is likely to fall short of that demand, creating a growing shortfall.

Uses

2.5 Tungsten's very high density and its high temperature properties are what make it unique and allow it to be used in a wide variety of applications. There are six main end-uses for tungsten, which in order of volume of use are:

- Cemented carbides (hardmetals).
- Alloy steels.
- Fabricated products.

— Superalloys.
— Heavy alloys.
— Chemicals.

Cemented Carbides

2.6 Cemented carbides, or hardmetals, are very hard, refractory, wear resistant materials that consist of metal carbides held in a bonding matrix. Cemented carbides are the main end-use application for tungsten.

2.7 Tungsten carbide exhibits extreme hardness and high resistance to abrasion up to very high temperatures. It is produced for widespread applications in "high-tech" tools, wear parts and, significant to the considerations of the Committee, mining tools, as well as for many sectors of the engineering industry. Tungsten in cemented carbides mining tools is therefore essential in ensuring access to all other critical or strategic metals.

Alloy Steels

2.8 Steel is an important end-use for tungsten, representing around 20–25% of global consumption, although there are large variations in demand between countries. Tungsten contributes to the increased hardness, wear resistance and higher toughness. Alloy steels comprise three distinct markets for tungsten; tool steels, stainless and heat-resisting steels, and alloy steels.

Fabricated Products

2.9 Significant amounts of tungsten are used in the manufacture of tungsten metal products such as lighting filaments and electrical and electronic contacts. Demand for tungsten has been affected by the phasing out of the traditional light bulb. However, tungsten is also used as filament in halogen lamps, and in electrodes for discharge lamp systems and arc lamps. As a result, substitution of traditional light bulbs has had less of an effect on tungsten consumption.

2.10 Tungsten is also used in electrical and electronic contacts because it is able to withstand arcing caused when circuits are made and broken, and it is resistant to wear and corrosion.

Superalloys

2.11 Superalloys are nickel, cobalt or iron based alloys with high contents of tungsten, molybdenum, tantalum and rhenium. Their important properties include, high-temperature strength, high creep strength at high temperature, high thermal fatigue resistance, good oxidation resistance, excellent hot corrosion resistance, air melting capability, air or argon remelting capability, good welding properties and ease of casting.

2.12 Superalloys are used in aircraft engines, marine vehicles, and stationary power units as turbine blades and vanes, exhaust gas assemblies and burner liners.

Heavy Alloys

2.13 Tungsten heavy alloys are a group of two-phase composites with the properties of high density, high strength and ductility. Applications include counterweights in aircraft, rotating inertia members, x-ray and radiation shielding.

2.14 Other alloys include those alloyed with cobalt, molybdenum and rhenium; and refractory alloys, where tungsten forms solid solution alloys with a number of other high melting point elements, notably niobium and tantalum.

Chemicals

2.15 The main tungsten chemical end uses are as a catalyst and in other uses such as the manufacture of semiconductor devices, in pigments, as a corrosion inhibitor, in phosphors (lasers, fluorescent tubes, oscilloscopes, colour television tubes), in absorbent gels, as oil additives, for fireproofing, as a fluxing agent and for hard surfacing.

2.16 Tungsten has a number of roles at a catalyst including:

— DeNOx catalysts for the removal of nitrogen oxides from combustion power plant stack gases.
— Catalysts for hydrocracking, hydrodesulphuration and hydrodenitrification of mineral oil products, maximizing recovery of light fuels from heavy crude and making the products more environmentally friendly.
— Other catalysts for dehydrogenation, isomerisation, polymerization, reforming, hydration and dehydration, hydroxylation, epoxidation, etc.

Tungsten Substitution

2.17 Due to its unique properties, there is relatively little opportunity, or incentive, to substitute tungsten in its major applications. Tungsten is relatively price inelastic (ie demand for tungsten does not automatically fall when prices rise). Tungsten-based products may face competition from products based on other materials but increases in the tungsten price have less of an impact.

Recycling

2.18 Tungsten scrap, due to its high tungsten content in comparison to ore, is a very valuable raw material. Overall about a third of tungsten demand is supplied from recyclate; this also enables the recovery of other critical and strategic metals such as cobalt, tantalum and niobium. Increasing recycling would reduce to a degree the need for new primary extraction of tungsten. However, the growth in demand means that even a very large rate of recycling could not satisfy demand.

3.0 Answers to Specific Questions Raised by the Commitee

Q1. *Is there a global shortfall in the supply and availability of strategically important metals essential to the production of advanced technology in the UK?*

A1.1 The concept of a shortfall in strategically important metals, such as tungsten needs to be considered not just in relation to our existing technology industries. Perhaps of greater significance is the future impact of a shortfall on those developing, and awaiting development, technology industries that we may not be able to develop because of restricted access.

A1.2 Conceptually, research into new technologies in the UK would not be constrained by shortfalls or limited access to tungsten. While the traditional end use market for tungsten remains strong, new technologies (new catalysts, new alloys, new uses in nanotechnology) based on the unique physical and chemical properties of tungsten are under research and development. Any limitation of access to tungsten would inhibit development of the resulting technologies into industrial scale applications in the UK.

A1.3 There is a developing global shortfall in relation to proven reserves of tungsten that are economically recoverable and "available", in the sense that there are no restrictions on extraction or sales. This shortfall flows from, and is exacerbated by, the dominance of China in reserves, production and consumption. China has also restricted operations within the country, limited mining licences, restricted exports, adjusted export taxes and shifted export quotas to favour "added value" products.

Q2. *How vulnerable is the UK to a potential decline or restriction in the supply of strategically important metals? What should the Government be doing to safeguard against this and to ensure supplies are produced ethically?*

A2.1 The UK is already vulnerable and affected by restrictions in the supply of tungsten. As China industrialises it will naturally seek to retain a greater percentage of tungsten for its own consumption, maximise the "added value" potential of any exports and seek sales agreements to recover scrap back to China. At the same time; as China improves its regulation of environmental, health and social impacts associated with some of its mining industry; the available supply from China may shrink.

A2.2 The UK has one of the most rigorous and fair planning and regulatory regimes in the World. This regime fits within a local democratic process and within a stable and trusted national political framework. Where the UK has resources and reserves of strategic minerals, the most ethical method of ensuring supplies of strategic minerals to our economy is to provide them from our own resources. Such action clearly removes or reduces any threat of external controls on supply to the UK.

A2.3 Unfortunately, policy for the identification, management and development of the metal minerals for the UK economy has relied for decades on the laissez-faire concept that other nations will provide. This has left metal minerals outside central government policy. The implications of this policy vacuum in a time of developing metal supply vulnerability are now being understood. What is therefore urgently required of government is strong "ownership" within government of metal minerals (and indeed all strategic non-energy minerals) and clear policy on the importance that the UK government attaches to providing minerals from our own resources.

Q3. *How desirable, easy and cost-effective is it to recover and recycle metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

A3.1 As described above a substantial level of recycling of tungsten already takes place. Currently tungsten scrap from the UK is exported for re-processing to other countries, including those where environmental and ethical issues are less certain. There is the potential to recover this scrap for recycling within the UK if a tungsten processing plant were to be constructed within the UK, probably on the back of processing primary ore from Hemerdon.

Q4. *Are there substitutes for those metals that are in decline in technological products manufactured in the UK? How can these substitutes be more widely applied?*

A4.1 As a general rule the concept of substitution only transfers demand from one strategic mineral to another strategic mineral. Further the development of new technologies, such as related to energy sources, appears to increase demand on strategic metals creating more pressure or a new shortfall position.

A4.2 There is very limited scope for substitution of tungsten by other metals in the primary end uses. Developing new technologies suggest that the demand on tungsten will increase because its valued and specific properties are non-substitutable.

Q5. *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

A5.1 The primary objective should be to work with our European partners on all aspects of securing supply of strategically important metals. However, for many metals the challenge cannot be restricted to recovery, recycling or substitution. Substitution often translates supply problems from metal "A" to metal "B" and is an illusory solution. Recovery and recycling can assist supply, but increasing demand, often arising from the very actions of seeking more efficient and less polluting technologies, produces an increase in demand which recovery and recycling cannot satisfy.

A5.2 The bigger challenge (bigger, because other solutions are favored more, but less effective), is the need to ensure that national policy addresses the need for primary supply from our own resources.

4.0 Conclusion

4.1 Wolf Minerals believes that the supply of critical and strategic metal minerals is now a significant issue for the UK and welcomes the review. The call for evidence by the Committee comes at an apposite time for the UK. The outcomes of the review can help the UK grasp the significance of the problem but also the opportunities. The outcomes can also help to put in place both the necessary "ownership" of metal minerals within government and the necessary supporting policies at UK national government level.

Wolf Minerals Ltd

17 December 2010

Written evidence submitted by the Society of Chemical Industry Materials Chemistry Group (SIM 08)

Background

[1] Materials Chemistry is a special interest group of the Society of Chemical Industry; it has approximately 400 members drawn from:

(i) The industrial sector, which represent a broad spectrum of basic research and development, manufacturing and processing technology as well as senior managers and directors who are responsible for wide ranging policy development.

(ii) Academics and emerging young scientists that constitute a core segment of UK fundamental and applied research and technology transfer.

[2] The Group, through the Society, is a major forum for bringing together groups of scientists from specific disciplines, fostering exchanges of ideas, forming research and technology networks, identifying future direction and formulating strategic policy.

Through beneficial collaborations with the Royal Society of Chemistry, the Institute of Materials, Minerals and Mining and the Institute of Physics it provides the main UK spine of interaction for all those interested in Materials Chemistry and related matters.

The Group and the Society membership is therefore a major source of knowledge and opinion relating to metals and alternative materials technologies; for this reason we wish to register our interest and our willing to contribute to this enquiry.

[3] We note the well established major general increase in the consumption of metals which began in the last century, shows no sign of abating and is likely to be exacerbated by high-volume emerging economies.

[4] We note also the potentially vulnerable position of the UK in that present sources of metals required to fulfil its own needs are largely external.

[5] Since metal recovery and processing are largely energy intensive processes, it is also clear that there exists a paradox in terms of national and world supply in relation to burgeoning green and environmental issues.

Specific Materials Chemistry Issues

[6] The Group and Society interest and expertise impinge on Strategic Metals in a number of key areas, these are described below.

[7] Metallurgists and other scientists working directly in the metal sector and specifically those responsible for strategic planning and new technologies; clearly these have a critical role in both problem solving and deciding lead policy matters.

[8] An additional but critical area is that of alternative materials; here, to give but a few examples, composites provide alternative structural materials, hard coatings (such as diamond and other plasma CVD methods) offer wear-resistance and bearing surfaces, porous carbons for battery and other energy uses and improved efficiency in metal dispersion for catalyst systems all have a huge amount to offer in relieving pressure on essential metal technologies.

[9] Related to [8] are emerging alternative processing technologies which increase efficiency in existing methods or offer new routes to end products with less waste etc. A typical example is low energy separation and extraction methods.

[10] Finally, there are related policy issues of fundamental research, technology development and transfer which in the mid to long term both improve greater efficiency in, and provide viable alternatives to, present metal solutions.

[11] In short, it is our opinion that, though complex, the problems associated with strategic metals are not insoluble and that, amongst others, the membership of the SCI has a critical contribution to make.

Professor Bob Bradley
(Chair SCI Materials Chemistry Group)
Dept. Of Materials
University of Oxford

16 December 2010

Written evidence submitted by the Mineralogical Society of Great Britain and Ireland (SIM 09)

Declaration of Interests

1. The Mineralogical Society of Great Britain and Ireland (Mineralogical Society hereafter) is a learned society that aims to advance the knowledge of the science of mineralogy, and its application to a range of subjects, including among others the exploitation, processing and recycling of economic minerals.

2. The Mineralogical Society has approximately 1,000 members, the majority of whom are students, researchers and academics from universities and other scientific institutions, in the UK, Ireland and abroad. Many of these scientists work in fields with direct application to the question of strategically important metals. These include the nature and properties of minerals; the processes by which they are formed and concentrated; extraction methods; metallurgy; and mineral processing. The Mineralogical Society has a number of Special Interest Groups, including an Applied Mineralogy Group.

Overview

3. Strategically important or "critical" metals have been the subject of a recent report by the European Union (EU), which identified a list of critical raw materials for the EU (http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm) . This submission assumes that the list of critical metals for the UK corresponds strongly to the EU list. The UK does not currently produce any of the metals on that list from primary indigenous sources, although potentially economic deposits of some metals do exist in this country; an example is the Hemerdon tungsten deposit in Devon. The lack of indigenous production means that the UK is vulnerable to security of supply issues.

4. Research carried out by scientists within the UK has the potential to address many aspects of critical metal supply, including:

— Understanding the processes by which ore deposits are formed, and identifying hitherto unrecognised deposits. Many of the critical metals on the EU list have only become economically important in recent times, and thus their deposits have been the subject of limited research.

— Understanding of mineral properties, which is fundamental to recovery of critical metals from waste streams and through recycling.

— Development of substitutes for critical metals.

Q1: *Is there a global shortfall in the supply and availability of strategically important metals?*

5. Although the known global reserves of critical metals may be limited at this point in time, it is anticipated that as market forces drive research and exploration, new reserves will be discovered and developments in

extraction and processing will allow these to be exploited. Global geological resources of these metals are thought to be considerable, although estimation of the total extractable resource is difficult. In the short term, geographical and political factors are of more concern: many critical metals are only available from a small number of sources, some of which are in the world's more unstable countries. The EU is almost entirely dependent on imports of most of the critical metals. There is thus a possibility that supply and availability of any of these metals could be limited at times in the next few years.

Q2: *How vulnerable is the UK to a potential decline or restriction in supply?*

6. The UK currently has no production of any of the critical metals from a primary source. UK supplies of these critical metals are dominantly from non-EU sources, and many critical metals are supplied from only one or two countries; for instance, almost all the world's tantalum is produced in the Democratic Republic of Congo. Political disruption in such countries could significantly affect supply of these metals to the UK.

7. The UK is considered to have significant reserves of some of the critical metals, particularly in the historical mining area of SW England, although areas such as the Highlands of Scotland and parts of Wales also potentially contain exploitable deposits. Issues of cost, environmental considerations, and planning have restricted mining in these areas in recent years. Clearly, exploration and mining of critical metals within the UK would provide the country with some security of supply, as well as bringing economic benefits to rural areas.

8. Despite the current lack of metalliferous mining within the UK, the UK is still a global centre for mining finance and home to two of the world's largest mining companies (Rio Tinto and Anglo American). There are many other mining and exploration companies and mining consultancies, of a range of sizes, based in the UK. They are working worldwide on a range of resources including critical metals, are contributing to the UK economy, and are in a position to aid the supply of critical metals for UK industry.

9. The UK has a reasonably strong research base in ore deposit geology, but relatively little research funding is currently directed into this area. Furthermore, only one university offers a degree course in mining engineering or graduate course in mining geology (Camborne School of Mines, University of Exeter), and the level of ore deposit geology taught as part of mainstream undergraduate geology courses is variable. To ensure that the UK retains the skills and knowledge needed to identify and exploit resources of strategic raw materials, it is essential that research and education in these areas is supported.

10. Promoting more rapid routes from exploration to exploitation of deposits is vital in ensuring security of supply. Efficient use of resources requires comprehensive understanding at the exploration stage of how a deposit will perform when processed through mining, concentration and extraction of the elements of interest. This "geometallurgy" needs interdisciplinary research between geologists, mineralogists, specialists in geostatistics, minerals and mining engineers.

11. On the subject of ethical production, it is important that mining of critical metals in developing countries is responsibly managed and associated with positive financial, social and environmental impacts. We note that it is possible to use a scientific approach to "fingerprint" materials and identify their source ore deposit. As an example, the German geological survey has used a variety of analytical techniques to "fingerprint" tantalum ores from Africa. Many organisations are working on methods to ensure responsible sourcing, and more research is needed to identify the best ways in which this can be ensured.

Q3: *How desirable, easy and cost-effective is it to recover and recycle metals?*

12. Recycling is one important strand of critical metal supply. However, many of the critical metals have only recently become important in components for new technologies, and thus the resource available to be recycled is limited. Further research into recycling processes is needed to increase efficiency.

Q4: *Are there substitutes for those metals that are in decline?*

13. Substitutes have not yet been identified for many of the critical metals that are used in new technology applications. Further research in this subject is urgently needed.

Q5: *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

14. Many scientists working in these fields already collaborate widely with other academics and colleagues in industry from around the world. The UK scientific community will continue to address these questions, but the availability of research funding is a key constraint.

The Mineralogical Society of Great Britain and Ireland

17 December 2010

Written evidence submitted by the Natural History Museum (SIM 11)

Background and Interests

1. The Natural History Museum (NHM) has a mission to maintain and develop its natural history collections to be used to promote the discovery, understanding, responsible use and enjoyment of the natural world.

2. The NHM has strong links to the mineral deposits research community in the UK through its association with the Mineral Deposits Studies Group (MDSG), the Mineralogical Society and the Geological Society, and its scientists have contributed to other submissions to the Committee from these groups.

3. The Department of Mineralogy at the NHM provides a national capability in the characterisation and research into naturally occurring minerals, rocks and ores. The Museum's collections are de facto the national collection of specimens of minerals rocks and ores, containing more than 550 type specimens of the 4~4500 mineral species identified worldwide. These collections form the basis for active research programmes where there is a fundamental need to understand the natural geodiversity of minerals, how they form, how they break down and how metals are incorporated into them.

4. Research and curation scientists in the Department of Mineralogy are influential members of UK-based and international mineralogical forums; for example we have a representative on the management group of the internationally respected web-based resource Mindat, which now forms an authoritative reference database of natural mineral species and their worldwide provenance. World-class laboratories underpin the research and curation efforts at the Museum meaning it has the capability to fully characterise natural minerals, a unique combined facility in the UK.

5. The NHM is active with both research and consulting projects with the minerals industry worldwide and so provides advice on diverse issues related to mineral occurrence and methodologies of processing. The NHM works with other UK agencies, for example it has provided specialists to work on contract projects with the British Geological Survey, where in-house expertise was lacking.

6. The Centre for Russian and Central Eurasian Mineral Studies (CERCAMS) is embedded in the Department of Mineralogy and is a research network that covers the CIS (Russia, Central Asia), Mongolia and China; all key emerging suppliers of metals to world markets. CERCAMS holds advanced knowledge on the mineral wealth of these regions and has an unparalleled collaborative network established with institutions in the region.

7. The NHM generates the world's only comprehensive database on carbonatites which are the most important host-rocks for Niobium and Tantalum deposits as well as containing vast reserves of Rare Earth Elements (REE).

Question 1: *Is there a global shortfall in the supply and availability of strategically important metals essential to the production of advanced technology in the UK?*

8. Projections suggest that there may be shortfalls of supply of some commodities in the medium term as indicated by the EU ad-hoc working group which reviewed "Critical raw materials" in 2010[1]. However, it should be pointed out that in general terms limits to current mineral extraction are a function of the energy costs of extracting at a profit. Figure 1 shows a graphical representation of this, indicating that supplies of most metals are actually virtually limitless but there is a "mineralogical barrier" to extraction defined by the inability to extract the metal feasibly below a certain concentration level.

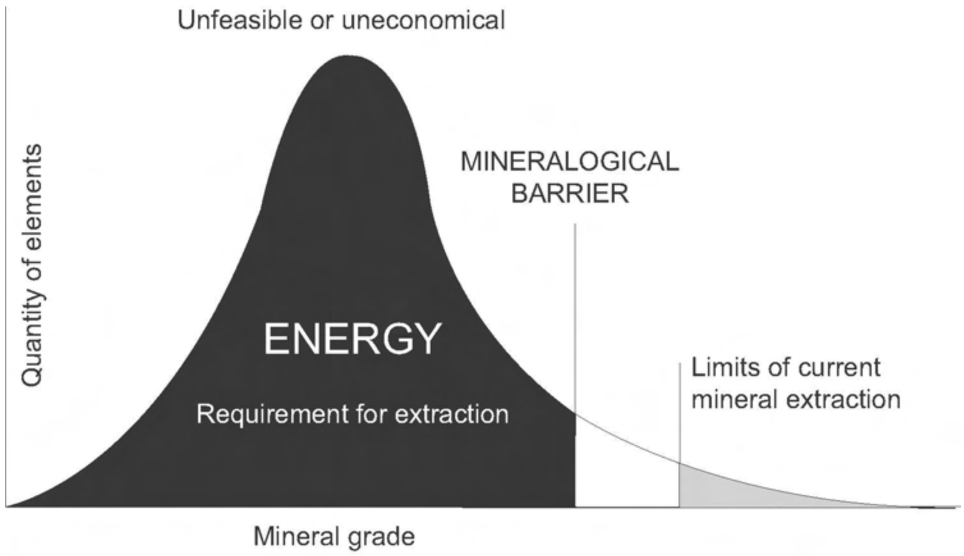


Figure 1*—Graphic representation of distribution of elements on the planet. Red area shows the limit to current extraction levels (at high mineral grade). The yellow area indicates where the bulk of the planet's resources of metal lie, at concentrations either uneconomic or unfeasible to extract, largely a result of energy costs (sourced from HCSS Report No. 02/1/10 Scarcity of Minerals[2]).*

9. Shortfalls in supply are often due to industrial reliance on specific mineral commodities which provide the metal of interest to an existing established commercial process. In many cases a high specificity of the mineral commodity mined and traded can result in either corporate or geographical monopolies of supply or in some case both. This is because often the rare mineral commodities are only economically concentrated in particular parts of the earths crust. A specific example would be the REE, which are essential for the manufacture of the magnets in such diverse products as computer disk-drives and new wind-turbines. 93% of REE supply is currently from China. A similar case exists for Niobium, essential to many electronic components, for which Brazil currently supplies 92% of world production.

10. We need to develop a better knowledge of the diversity of minerals containing the specific metal needed and their worldwide distribution. This knowledge would enable us to identify new locations for the potential supply of future metal needs. Characterised collections of naturally occurring mineral species such as those held at the NHM form important research resources for this type of initiative.

11. Industry responds to supply pressures with investigation of new supply streams, either by utilising substitute minerals from which the element is sourced or in some cases substituting another element (eg Palladium substituting for Platinum in vehicle catalytic converters). However, such work needs research which can be pursued in industry-academic partnerships. One fruitful area of research would be to seek new mineral sources for strategic metals which may be held in known but currently unexploited deposits (or waste materials). The key to unlocking these potential supplies is the development of alternative processing technologies that might successfully be employed on the new resource streams. An example of this is a project—hosted at the NHM—in which the application of new hydrometallurgical technologies to the processing of oxide Nickel ores (a technology pioneered by a UK-based Plc) is being investigated by our mineralogists. This work results in formerly uneconomic sources of Nickel, which are actually abundant in the eastern Mediterranean area of Europe, becoming attractive for future processing. Another good example is the NHM mineralogical work on the new Lithium mineral Jadarite, also carried out for a UK-based Plc. Lithium is currently sourced from the mineral spodumene which is mined in Canada and Australia but also from playa brines in South America. The recent identification of a potential new source of Lithium in Europe means that an alternative supply from a previously unknown source is possible, should the alternatives become unavailable. With more encouragement, more of this type of work could cover the full range of strategic metals, establishing a complete "geodiversity" inventory of strategic metal mineral species that may form future extractable reserves, which might be mapped against diversity of supply, cost of recovery and other factors.

12. A vertically integrated approach to mineral deposit research is needed with linkages between geologists, metallurgists and engineers in order to be able develop new innovative processing techniques. This combined research of "geometallurgy" could allow either the substitution of new mineral sources for a particular metal or alternatively have the effect of being able to move the "mineralogical barrier" shown in Figure 1 significantly to the left through novel, more energy efficient processing. Research council funding might be focused towards this area of applied mineral science. Current barriers too this could be the fact that this type of research bridges the funding briefs of NERC and EPSRC which may dissuade research projects in this field.

Question 2: *How vulnerable is the UK to a potential decline or restriction in the supply of strategically important metals? What should the Government be doing to safeguard against this and to ensure supplies are produced ethically?*

13. The UK is vulnerable to restriction of strategically important minerals. The UK currently produces none of the strategic metals and the secured sources within the EU yield only minor amounts of Antimony and Tungsten but no Niobium, Tantalum, REE or Platinum Group Elements (PGE). It is therefore imperative that UK institutions, like the NHM who have specialist knowledge and skills applicable to the development of secure resource streams play a role in research projects where such commodities are being evaluated.

14. A key problem in assessing the reserve and resource issues that face strategic metals is the current patchy level of knowledge about resources on a global scale. Whilst the "western" economies are relatively transparent about their resources, key countries such as Russia and China have historically considered resource statistics as state secrets and consequently it is still even now difficult to ascertain accurate data for these territories (for example PGE supply was a state secret in Russia until 2005). The NHM's CERCAMS group in collaboration with Russian other CIS state entities has developed a internationally recognised expertise in generating deposit and resource information for the CIS, China and Mongolia. It is apparent that commodity companies from Asian manufacturing economies of China, Korea and Japan are aggressively acquiring interests in both mineral deposits worldwide and taking large equity stakes in international resource companies, including UK-based companies (eg Chinalco 12% of Rio Tinto). The German government acknowledge this lack of market transparency in their review of strategic metal supply for German industry and announced in April 2010 that "*it is important that we increase transparency in the resource markets*". In the last five years some countries have changed their investment and mining laws to protect resources that are seen as being of national economic and strategic importance by limiting international investment in key deposits (eg Russia's Foreign Strategic Investment Law—2008).

15. With regard to ethical supply, it is possible to provenance ("fingerprint") certain mineral commodities using information on their chemistries and associations. It may be possible to implement a "certificate of origin" scheme that could track minerals along the supply chain from mine to market. Industry-led efforts in this field include pilot schemes by the Electronics Industry Citizenship Coalition and the International Tin Research Institute. The Kimberley Process, set up in 2003, addresses the trade in so-called blood diamonds and is the most high-profile of this type of initiative. The US has partially responded to ethical issues of mineral supply by recently introducing the Reform and Consumer Protection Act (July 2010), which requires any US-listed company to publicly disclose whether its products contain materials sourced from zones of conflict. The type of forensic mineralogy to track where minerals might be sourced from demands good analytical information from material, cross-referenced with well characterised and provenanced samples. The laboratories and national collections of the NHM can provide both the analyses and reference material for such an initiative.

16. New minerals can be substituted as new sources of supply, on example is the extraction of Nickel from lateritic ores which is set to overtake the amount of Nickel extracted from sulphide ores in the next three to five years[3] . There is a need for more information about the mineral diversity ("geodiversity") of the strategic metals so that a better assessment can be made concerning their distribution and the location of future new resources. Again, characterised collections of these naturally occurring are needed for such assessments.

Question 3: *How desirable, easy and cost-effective is it to recover and recycle metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

17. The recycling of metals from discarded products is essential. However, another source of metals may be waste mineral products.

18. Waste mineral products in some cases can form a future resource. We therefore need an assessment of potential supply of strategic metals not only from recycled products but also from discarded mine waste. Waste may be in the form of unprocessed mine rock dumps or slimes produced during the processing of other commodities and may actually be an untapped resource of some of the strategic metals. Across the EU states and elsewhere such waste material may exist but needs careful characterisation to assess its suitability. A more careful inventory of waste materials should be made to assess suitability as new resources.

Question 4: *Are there substitutes for those metals that are in decline in technological products manufactured in the UK? How can these substitutes be more widely applied?*

19. As stated in point 16 above, an understanding of the full geodiversity of possible natural source materials (minerals) is needed to be able to assess our future commodity needs to enable UK industry to rapidly respond to future trends.

20. The application of substitute supplies needs buy-in from industry to change the currently traditional sources and therefore support for industry-academia research into these new processing streams and methods is therefore necessary.

Question 5: *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

21. Applied research into mineral deposits clearly aids the exploration for new resources. UK academic institutions have a strong track record in collaborative research projects with UK-based international mining companies at a range of levels. The UK government must ensure support for this research is strengthened from the current low base via focused funding for universities and public research in order to continue helping the development of new resource streams. Encouragement to create vertically integrated research which would look at metal sources from their discovery through to formation of a successful processing and waste management strategy is essential and we highlight the emerging research discipline of "geometallurgy" which unites geologists, mineralogists, metallurgists and mineral processing engineers in the search for the efficient extraction of metals.

22. Waste streams from past mining and metal processing in the UK and elsewhere could potentially be substitute sources for some of the strategically important metals currently obtained elsewhere. One example identified by CERCAMS at the NHM is the extensive waste dumps from copper mining in Central Asia, a potential alternative source for PGEs and thus the development of better collaborative research links with countries where large industrial waste streams are known (eg CIS countries) may bring opportunity for UK research teams and industrial groups.

Conclusions

23. In conclusion, the UK should act swiftly to implement measures or make specific recommendations in order to mitigate some of the supply issues faced. Much of this can be done by encouraging closer research links between all parties involved in the location, extraction, processing and trading of metals. Specific research initiatives may be warranted in the field of "geometallurgy" where the UK could make a greater contribution using our existing research centres of excellence, such as the NHM. The NHM is ready to help contribute towards these aims and would welcome the chance to discuss this further.

24. Underpinning the national research capability relating to the resource sector is essential to secure facilities and expertise to advise on strategic metal sources and supply. Focused government support for the mineral deposit research base in the UK public sector, including the NHM and in universities needs to be maintained and in some areas increased or national capability will be lost. Applied research, not close enough to market to be directly supported by industry, has been poorly supported by NERC in recent years, largely as the research may bridge between research council remits. We urge there to be more attention paid to this. Research in this sector is critical both for the maintenance of capacity and also for tackling the challenges of efficient extraction of resources in an environmentally sustainable way, with less waste generation and more carbon neutral processing.

25. In line with other EU states (eg Germany and France), the UK government might consider installing a qualified advisory group (agency, commission, committee) bringing together the best expertise from, for example, the British Geological Survey, universities, the NHM, other research institutions, NERC and EPSRC together with experts from the UK-based minerals industry, commodity traders, metal processors and the end users in order to regularly monitor and advise on issues.

References

[1] Critical Raw Materials for the EU, Report of the ad-hoc Working Group on defining critical raw materials, European Commission, July 2010: http://ec.europa/enterprise/policies/raw-materials/documents/index_en.htm

[2] Scarcity of Minerals: A strategic security issue, 2009: The Hague Centre for Strategic Studies: No. 02|01|10

[3] The Past and the Future of Nickel Laterites: PDAC 2004 International Convention presentation: Dr Ashok D Dalvi; Dr W Gordon Bacon; Mr Robert C Osborne, Inco Limited

Department of Mineralogy
Natural History Museum

17 December 2010

Written evidence submitted by Construction Materials Group, Society of Chemical Industry (SIM 12)

1. *Is there a global shortfall in the supply and availability of strategically important metals essential to the production of advanced technology in the UK?*

[1] Yes—and not just in metals. For example, the last remaining UK fluorite mine (Glebe, Derbyshire) has been closed by it new owners (INEOS) with the loss of 65 jobs. The asset is to be sold to a Mexican firm (Mexichem) by the end of 2010 (who will import the mineral from overseas) and will impose considerable costs in the acquisition of new processing equipment by their UK customers. Note that fluorite is an essential flux for metal refining and the principal pre-cursor to production of hydrofluoric acid.

[2] In considering supply and availability, we must distinguish between primary and secondary production and between home and overseas sources. Our indigenous metals reserves, though once extensive, are now considerably depleted, being worked extensively from the dawn of the industrial revolution to the present. We are dependent on the import of metals from overseas. Over the last decade, our ability to refine metals in the UK has reduced markedly; seeing the closure of our last copper smelter (James Bridge) our last zinc Smelter (Britannia) our major aluminium refiner (Anglesey) and the withdrawal from the secondary lead business by Xstrata (formerly Britannia Refines Metals on the Kent coast). These changes leave the country increasingly dependent on overseas markets and technologies and severely limiting our ability to recycle the metals which we discard.

[3] As to the impact on *"the production of advanced technology in the UK"* we can only speculate about the impact of the loss of skills, facilities and knowledge to this country. In terms of technological development (at which we still excel) the availability of strategic metals has not yet had a major impact on our R&D capability. However, our demonstrable inability to develop world-class research into profitable business is undoubtedly restricted by the lack of opportunity to develop R&D ideas with industrial sponsors, as strategically important businesses have been allowed to decline.

2. *How vulnerable is the UK to a potential decline or restriction in the supply of strategically important metals? What should the Government be doing to safeguard against this and to ensure supplies are produced ethically?*

[4] There are numerous examples of metals whose supply limits industrial growth. Indium for display technology; lithium for high energy density batteries; the rare earth elements terbium, lanthanum and neodymium, are all at the forefront of technological development and all are in short supply. There are two drivers to this. The "less common" light metals, lithium and titanium are abundant in the earth, but are difficult and energy-intensive to refine. The UK is at the forefront of titanium refining R&D (see the FFC process[i]) and lithium is produced and recycled by Umicore in Belgium amongst others. On a recent visit to Umicore I was unsurprised to hear that the greatest restriction on the efficient recovery of lithium from batteries is that they are rarely recycled! Having paid a considerable sum for a mobile phone imparts a sense of value in its owner, which persists long after it has ceased to be used. Most of the redundant phones in the western world lie in a drawer! There is an obvious initiative the government could take to increase the supply of this metal—any incentive to recycle mobile phone and other batteries would offer huge savings over refining lithium from minerals such as spodumene. The UK does not have economic deposits of lithium, the bulk is mined in Bolivia, with Australia, Chile, Afghanistan and China holding considerable reserves.

[5] The issue of Rare earth Elements is much further from our control. The automobile industry uses tens of thousands of tons of rare earth elements each year, and advanced military technology depends on these elements also. Much of our "green" technology depend on them, including wind turbines, low-energy light bulbs and hybrid car batteries. Of the 17 REE elements known, China holds 97% of the reserves and has threatened to stop, or severely restrict their export, preferring to export them as high-value products. The problem is that at present, there is an insufficient quantity of these elements in circulation to make their recycling worthwhile.

3. *How desirable, easy and cost-effective is it to recover and recycle metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

[6] It is relatively easy to recover elements from products, but this comes with an energy penalty and often generates wastes which often have no practical use. Developments in recycling technologies have been supported in the UK through the Research Councils, the Knowledge Transfer Networks and Technology Strategy Board and their continued success should be safeguarded.

[7] To increase the recycling of metals generally, a strategic review of the efficiency with which industries and local authorities deal with their waste inventory in needed. This should be followed by compulsory sorting of all metal wastes from households and businesses by the consumer and collection by local authorities. It is indefensible in a modern society to throw any metals away.

[8] We need a national review of metallic wastes in the UK, quantifying the amounts and locations of each metal in the national waste inventory and then to identify routes to their recovery. Once we understand the nature of the problem, we will be in a position to address it. At present a large, but unknown quantity of metals are neither in use, nor in the recycling circuit. It would be in the nation's interest to minimize this quantity though recycling incentives.

[9] You ask how recycling can be encouraged and this is effective by both carrot and stick. To impose fines on people discarding metal waste is one option as would be the provision of a VAT discount on new phones; available when trading in an old one. The safety of recycling is another issue. For example, the lead in a car battery has potentially great toxicological impact. Thankfully, it takes a very long time before it is adequately dissolved and this is often sufficient for its impact to be diluted and dispersed. By and large, industrial safety is excellent in the UK and increased recycling of metals would seem to pose no new risks to those already accounted for.

[10] Lastly, the ethics of recycling are occasionally very poor indeed. We have all seen waste ground where the insulation has been burned from (often stolen) cables, prior to their sale as scrap copper. This localized and relatively small-scale crime is very difficult to prevent. Similarly, the export by sea of huge quantities of metals has ethical implications in that their initial "reprocessing" in India, China and the Philippines is often crude and environmentally damaging. In both cases, we have a legislative framework in place which, by and large, prevents ethically unsound practice in the UK, but once out of our control becomes very difficult to manage.

4. *Are there substitutes for those metals that are in decline in technological products manufactured in the UK? How can these substitutes be more widely applied?*

[11] Current technologies do not provide suitable alternatives to the rare earth elements, which are of increasing concern. As stated above the opportunities for their recycling are very limited at present. We do have the facility for recycling platinum group metals from exhaust catalysts through Johnson Matthey, but the business is dependent on global car sales. At present, it is not very attractive to them, but as the major PGM operators in the UK, they should be encouraged. Globally, Anglo American controls almost half of the world's reserves of platinum group metals and is the dominant force in their primary extraction. Much has been said about recovery of PGM dust from road gulley waste and various proposals have been made to address this. Again, this is an area ripe for development. Research into alternative catalysts should be promoted vigorously, but no obvious replacements to PGM elements seem attractive at present.

5. *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

[12] The UK R&D community depends in part, on the strength of our government officials in effective lobbying in Europe. Through the European Technology Platforms, we have an opportunity to work with partners in Europe in shaping the political agenda for strategic materials R&D. We need to ensure our representatives are well-versed in science and technology and are in an informed position to conduct these negotiations to this country's long-term advantage. There is no room for weakness here, as the German, Dutch and Scandinavian representatives seem especially able in this respect.

[13] Perhaps the greatest return for the taxpayer's money would be to provide the TSB or KTNs with the resources necessary to find prospective partners and opportunities in Europe and to maximize the participation of the UK research community. This would require a small group of people to monitor both the "Official Journal" and "Framework Programme" literature and to disseminate this information in the UK. Moreover, involvement with the Directorates General and Technology Platforms will provide a valuable conduit for information transfer in both directions. The larger UK companies do this commercially and it would be an easy step for the government to take, involving little cost for potentially great rewards. In these times of both austerity and information overload, this might go some way to increasing our international collaboration, at least in Europe.

[14] In conclusion, Britain no longer meets its own needs in terms of metal extraction and its ability to recycle the metals it has used has declined considerably in recent years. Exporting our metals for recycling elsewhere comes at a cost to both the economy and environment. Moreover, it leaves us increasingly vulnerable to the fluctuations of the international metals markets and the political whim of monopoly supplier nations.

[15] Our greatest asset is in expertise across the entire supply chain, from exploration, mining, beneficiation and smelting, to novel technologies for recycling of secondary metals. Britain produces some of the most sought after graduates in these technologies and has generated a wealth of knowledge far greater than might be expected for our relatively small population. Our R&D assets in these critically important areas should be protected at all costs to ensure the materials security of the nation.

Reference

[i] G Z Chen, D J Fray, T W Farthing (2000). "Direct Electrochemical Reduction of Titanium Dioxide to Titanium in Molten Calcium Chloride". *Nature* 407 (6802): 361–4

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17 December 2010

Written evidence submitted by Research Councils UK (SIM 13)

Executive Summary

- Much of the concern over physical exhaustion of geological reserves of strategically important metals is likely to be misplaced, though there are no grounds for complacency.
- Due to the combination of 100% dependence on imported supplies, a high concentration of production in relatively few countries and low substitutability and recycling rates, the UK is vulnerable to restrictions in supply of some metals.
- New technologies required to develop the Green Economy will create a new source of demand for some strategically important metals. To ensure such technologies contribute to the Green Economy, carbon emissions and other environmental impacts associated with mining and processing of strategically important metals should be minimised.
- Scientific research has a critical role to play in numerous areas including:
  - Understanding earth processes and properties that produce mineral deposits and developing new mineral exploration technology, both to expand existing reserves and identify new resources.
  - Assessing the environmental implications of exploiting minerals important for the Green Economy, including whether extraction can be undertaken with a lower carbon footprint.
  - Developing alternative or replacement materials for strategically important metals in products.
  - Improving processes for recycling and reuse and doing more with less.

Introduction

1. Research Councils UK (RCUK) is a strategic partnership set up to champion the research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk.

2. This evidence is submitted by RCUK on behalf of the Research Councils listed below and represents their independent views. It does not include or necessarily reflect the views of the Knowledge and Innovation Group in the Department for Business, Innovation and Skills. The submission is made on behalf of the following Councils:

- Engineering and Physical Sciences Research Council (EPSRC).
- Natural Environment Research Council (NERC).
- Science and Technology Facilities Council (STFC).

3. NERC comments were provided by the British Geological Survey, NERC Swindon Office and Professor Louise Heathwaite, NERC Theme Leader Sustainable Use of Natural Resources (SUNR).

Background

4. Recent studies in the EU, USA, Japan, UK and elsewhere have attempted to identify the most “critical” metals and minerals[1, 2, 3, 4] so called because of their increasing economic importance and high risk of supply shortage. Hitherto, global consumption of critical metals has been relatively small.

5. The NERC British Geological Survey (BGS) has monitored global metal production and trade for almost 100 years. This knowledge and experience, together with BGS’ active participation in the recent EC study on defining critical raw materials[1] leads us to suggest the following are considered the most “critical” strategically important metals: antimony, beryllium, cobalt, gallium, germanium, indium, lithium, niobium, platinum group metals, rare earths, rhenium, tantalum, tungsten.

6. Consideration of future demand for these metals is important, a major source of which will be new technologies required to develop the green economy (see Annex 1 for examples of driving technologies for different metals). For example, demand for gallium in emerging technologies may increase by a factor of more than 20 between 2006 and 2030[1]. For indium, germanium and neodymium, the factors are 8, 8 and 7, respectively, over the same period. This concern is the focus of a proposed £6 million major research programme on “Mineral resources: security of supply in a changing environment” led by the SUNR[5] theme for NERC. The focus would be to understand formation processes of metals important to the green economy and the environmental implications of their extraction and whether this can be undertaken with a lower carbon footprint.

7. Industry will make choices to use specific materials for a particular application, device or product, based upon many factors—for example prior experience, availability, performance and cost. There is a strong role for materials science and engineering researchers to expand the options available to companies. The two areas where research has a critical role (often supported through EPSRC) are:

- Replacement materials—developing alternative materials with the required characteristics and then demonstrating performance in use.
- Processes for recycling and reuse—in order to recover strategically important materials, reduce the need for primary extraction of materials or achieve other environmental benefit (eg energy reduction).

8. Though outside the scope of this Inquiry, there is concern over the shortage of Helium 3 and 4 used in neutron detectors such as the STFC ISIS facility and in MRI scanners in hospitals. This is a potential limitation for future research and clinical applications, particularly related to lung imaging. STFC scientists and engineers are actively developing alternative technologies to overcome the Helium 3 shortage.

Question 1. *Is there a global shortfall in the supply and availability of strategically important metals essential to the production of advanced technology in the UK?*

Physical Availability of Metals

9. Before considering UK supply, it is necessary to address the generic issue of physical availability of metals in the Earth’s crust. The reality is that despite increasing metal production over the past 50 years, reserve levels have remained largely unchanged[2]. Indeed, recent reports suggest there is ample supply of rare earth metals in US deposits[6,7].

10. Concerns regarding physical exhaustion of metals may be based on an over-simplistic view of the relationship between reserves and consumption (ie number of years supply remaining equals reserves divided by annual consumption). Metals of which we know the precise location, tonnage and which we can extract economically with existing technology—known as “reserves”—are tiny in comparison to the total amount. Consumption and reserves change continually in response to a) scientific advances and b) market forces, as outlined below.

(a) Scientific advances—As our scientific understanding improves, we can replenish reserves from previously undiscovered resources. For example, mineral deposit types which were largely unknown 50 years ago (such as porphyry deposits which are now the principal sources of copper, molybdenum and rhenium) contribute significantly to global reserves. These were discovered and developed largely as a result of improved understanding of their formation.

[1] European Commission (2010) Critical Raw Materials for the EU. Report of the ad-hoc working group on defining critical raw materials. http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

[2] National Research Council (2008) Minerals, Critical Minerals and the US Economy. National Academies Press, Washington.

[3] Ministry of Economy, Trade and Industry Japan (2008) Guidelines for securing national resources. http://www.meti.go.jp/english/press/data/pdf/080328Guidelines.pdf

[4] Oakdene Hollins (2008) Material security for the UK economy. Report for DBIS (Technology Strategy Board) http://www.oakdenehollins.co.uk/pdf/material_security.pdf

[5] http://www.nerc.ac.uk/research/themes/resources/

[6] The Principal Rare Earth Elements Deposits of the United States—A Summary of Domestic Deposits and a Global Perspective By Keith R. Long, Bradley S. Van Gosen, Nora K. Foley, and Daniel Cordier US Department of the Interior/ US Geological Survey Scientific Investigations Report 2010–5220 Nov 17 2010.

[7] http://www.usgs.gov/newsroom/article.asp?ID=2642

(b) Market forces—Market forces influence reserve size as most metals occur in graded deposits: if prices rise, reserves will extend to include lower grade ore; if prices fall, reserves will contract to include only higher grade material.

11. Although physical exhaustion of primary metal supply is very unlikely, there are no grounds for complacency. Our knowledge of transport and concentration processes of many strategically important metals is very poor; consequently collaborative science is vital in predicting and finding deposits of strategically important metals. Through its "Metals and Minerals for Environmental Technology" project, BGS carries out research in the UK and overseas, in conjunction with academia and industry, on the Earth processes and properties that produce mineral deposits, on novel resources for environmental technology (initially focusing on rare earths) and on new mineral exploration technology.

Environmental Considerations

12. The environmental costs of mineral resource extraction, processing and use present a long term threat to UK supply. It is critically important to understand how to decarbonise the extraction process. Around 3% of total global energy demand is used solely to crush rock for mineral extraction; carbon emitted as a consequence represents a significant environmental limit to our resource use. Major research and innovation is required in order to break the current link between metal use and greenhouse gas emissions.

13. Current examples of low carbon resource extraction technology include in-situ leach mining (eg of uranium) and microbial bio-leaching (eg of copper and nickel) from extracted ores. As long as the environmental impact can be minimised, such processes may significantly extend the resource base by allowing working of previously uneconomic ore types and grades.

14. The proposed NERC SUNR programme on "Mineral Resources" (see paragraph 6) will (if funded), support research designed to minimise the carbon and environmental footprint of future use of mineral resources.

Resource Distribution and Geopolitics

15. Uneven resource distribution and geopolitics present threats to UK supply. Metal deposits are unevenly distributed across the globe and patterns of supply and demand shift continually. There is rapidly increasing demand from emerging economies such as Brazil, Russia, India and China.

16. The likelihood is that tensions over resources will increase over the next few years. The UK currently has a world-class capability to monitor and analyse global mineral production, consumption, trade and reserves[8]. This should be exercised in conjunction with other EU member states, the US and Japan in order to forecast future security of supply challenges.

Question 2. *How vulnerable is the UK to a potential decline or restriction in the supply of strategically important metals? What should the Government be doing to safeguard against this and to ensure supplies are produced ethically?*

UK Imports & Reliance

17. The table in Annex 2 shows data on imports of strategically important metals into the UK and, for comparison, into the EU 32. Note that both the UK and the EU are currently 100% dependant for supply of these metals, as such, the UK is vulnerable to decline or restriction in their supply. A major deficiency in these figures is that they do not show imports embodied in finished and semi-finished goods (such as cobalt and lithium contained in rechargeable batteries). To our knowledge no reliable statistical data exists on this and therefore it is difficult to quantitatively assess our overall vulnerability to decline or restriction.

18. There have been and will be many important technological developments which incorporate strategically important metals, for example:

— The UK is a world leader in the manufacture of auto-catalysts based on platinum group metals imported from South Africa and Russia. Import levels and consequent vulnerabilities in the EU are even greater, and pose a significant risk to UK manufacturers and consumers who import vital components and finished goods from elsewhere in Europe.

— There is an enormous projected growth in the demand for lithium for electric vehicle batteries, including Nissan's plans to manufacture them in the UK.

— The technology required to deliver the government's plans to build a "green manufacturing" sector eg solar cells, depends on the availability of some strategically important metals.

19. Research Council funding (via EPSRC) has facilitated the development of new materials and devices that rely on the inclusion of strategically important metals to deliver their desired properties. Advances have had large and varied impacts on our economy and society. These include key advances in the electronics industry, developments of new methods for energy generation, conversion and storage and significantly improved construction and engineering applications of newly created alloys.

[8] British Geological Survey (2010) Mineral Statistics home page: http://www.bgs.ac.uk/mineralsuk/statistics/home.html

20. Shortages in the supply of Rare Earths and other strategically important materials would have a negative impact on the development of key UK-based large scientific facilities, such as Diamond and ISIS, operated by STFC and its partners, as well in other areas eg the development of the next generation of solar cells.

21. Some strategically important metals are derived as by-products (or coupled products) from the extraction of "carrier metals" from ores in which they present in low concentrations. Examples include gallium (found in aluminium ore) and germanium (found in zinc ore). Production from these ore types is predominantly driven by demand for the carrier metal. This factor may constrain any possible increase in production of the coupled product should demand increase independently of the carrier metal.

Safeguarding Supply

22. In general, we would subscribe to the recommendations made in the recent EU Critical Raw Materials report[9] as a way forward in addressing potential decline or restriction in supply. Recommendations include better knowledge of indigenous resources, improved and consistent statistics on mass flows, proactive trade policy with regard to strategically important metals (this needs to be carried out at the EU level in order to achieve sufficient critical mass when negotiating with other powerful trading groups) and policies to encourage recycling, reuse and resource efficiency. It should be noted however, this report is primarily concerned with access to raw materials and not to understanding their life cycle or implications of use on the environment.

23. An emerging alternative approach to maintaining supply is collaboration or even vertical integration of mining companies and industrial consumers. This provides certainty for the metal producers and security of supply for manufacturers[10].

24. In the past, stockpiling has been used by governments as a mechanism to reduce vulnerability. Whilst this approach has been seen as expensive and ineffective, some countries and private companies retain stockpiles.

25. The Research Councils engage with forums such as the Materials Knowledge Transfer Network (KTN), the Chemistry Innovation KTN and the Inter-Departmental Materials Coordination (IMC) group—a cross government group led by the Department of Business, Innovation and Skills and involving DEFRA, MoD, NPL, the Technology Strategy Board and other partners. These interactions allow us to feed in relevant information about current research and new developments and thus to develop a strategic approach to addressing the issue.

Ethical Production

26. Wealth released as a result of minerals extraction is simultaneously an opportunity and a threat to the development prospects of a country. It is likely that the bulk of primary supply of strategically important metals will come from the developing world. Although mineral endowments should enable poorer countries to embark on a path to economic development, the evidence shows that resource- rich developing countries often move in the opposite direction toward poverty and instability.

27. Inter-governmental agreements (such as the UK-led Extractive Industries Transparency Initiative) and the rise of corporate responsibility initiatives amongst the western mining sector (such as the Global Mining Initiative) have made major advances in improving the social and environmental impact of mining in the developing world. A serious challenge to this improvement is the rise of mining enterprises based in large emerging economies, but operating word-wide, which can adhere to different ethical standards to those established in developed economies.

28. Although formalised extraction by large enterprises is the familiar face of mining in the west, informal artisanal and small-scale mining (ASM) is a major extractive activity in the developing world. Of the listed critical metals, only tantalum-niobium (sometimes known as "coltan") is produced in any quantity by ASM. The long-running civil war in the Congo is, in part, caused by conflict over control small-scale coltan mines. Millions of people worldwide are economically dependent on ASM and the social, environmental and economic issues associated with ASM pose a considerable developmental challenge. Aid donors (including the UK) must recognise and accept the importance of ASM as a livelihood for many poor people and work with governments and NGOs in developing countries to improve the social and environmental performance of this sector.

Question 3. *How desirable, easy and cost-effective is it to recover and recycle metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

29. Recycling, substitution and resource efficiency are hugely important in meeting the challenge of burgeoning demand and should be the focus of future efforts towards the sustainable use of natural resources.

[9] National Research Council (2008) Minerals, Critical Minerals and the US Economy. National Academies Press, Washington.

[10] Ernst and Young (2010) Material risk: Access to technology minerals. http://www.ey.com/Publication/vwLUAssets/Material_risk:_access_to_tecnology_minerals,_Sept_2010/$FILE/Material%20risk_final.pdf

30. Research councils are investing in research looking at the long-term sustainable use of materials:

— NERC are proposing a major £15 million initiative on Resource Recovery from Waste led by the SUNR and the Environment, Pollution and Human Health[11] science themes, and involving other Research Councils.

— As part of the Sustainable Urban Environment programme EPSRC funded a consortium led by the University of Southampton to investigate Strategies and Technologies for Sustainable Urban Waste Management[12]. This research looked to improve our understanding of waste treatment and material/energy recovery and our understanding of resource and energy flows through and within urban environments.

— The EPSRC Centre for Innovative Manufacturing in Liquid Metal Engineering[13] at Brunel University is investigating more cost-effective and sustainable processes for metal engineering. If successful this research will dramatically reduce the energy consumption, carbon footprint and overall environmental impact of the metal-casting industry. Long term the knowledge gained from this funding could be applied to strategically important metals.

— EPSRC plans a major focus within its next Delivery Plan on sustainable manufacturing. This will address a range of sustainability challenges, including energy and resource efficient manufacturing, materials reprocessing and sustainable design approaches.

Limits to Recycled Supply

31. In general, the free market has so far been ineffective in encouraging recycling and resource efficiency. Policy and related economic instruments have proved more effective. For example, the Aggregates Levy has contributed significantly to the UK's high level of aggregates (ie crushed stone, sand and gravel) recycling (second highest in Europe)[14].

32. For the foreseeable future, the vast bulk of our requirements for strategically important metals will have to be sourced from primary resources within the crust. The upper limit on what is available for recycling is determined by what comes back from society; the ceiling on this is what we consumed 40 to 60 years ago. By way of illustration, global consumption of copper in 1970 was approximately eight million tonnes per annum. Five million tonnes was from mining, with three million tonnes from recycling. In 2008 global copper consumption was about 24 million tonnes, of which eight million tonnes are derived from recycling, with the remaining 16 million tonnes from primary production.

33. For most other metals recycling provides only 10–20% of demand, although work by UNEP[15] and research carried out as part of the recent European Raw Materials Initiative[16] suggests that recycling rates for elements such as Gallium, Indium, Tantalum and Rare Earths are currently less than 1%. Even if recycling rates for these materials were much higher, we must recognise that the strategically important metal "resource" currently residing in the anthropogenic environment is very small compared to that needed to meet predicted demand from manufacturers of electric vehicles, wind generators, solar panels and digital devices.

34. Assessing the further potential contribution of recycling to meeting demand within the UK is hampered by lack of figures on imports of strategically important metals contained in finished and semi-finished goods (see paragraph 17). This makes it difficult to quantify the amount of strategically important metals residing in society which may become available as a "resource" for recycling.

Question 4. *Are there substitutes for those metals that are in decline in technological products manufactured in the UK? How can these substitutes be more widely applied?*

35. When developing new materials and devices researchers need to consider:

— If strategically important metals are essential to provide the required properties.

— If there are alternative materials that will display the same properties.

— What the minimum level of the required element is that will allow the same properties to be exhibited.

— What the environmental implications of metal use are and how this will change in the future; whether environmental constraints might limit future use of minerals.

— The future supply of materials and whether developing a new material or device with significant quantities of strategically important metals is viable.

— The end of life and how to recapture, reuse or recycle strategically important metals.

[11] http://www.nerc.ac.uk/research/themes/health/

[12] http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=GR/S79626/01

[13] http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/H026177/1

[14] Mineral Products Association (2009) Sustainable development report http://www.mineralproducts.org/documents/MPA_SD_Report_2009.pdf

[15] http://www.usgs.gov/newsroom/article.asp?ID=2642

[16] National Research Council (2008) Minerals, Critical Minerals and the US Economy. National Academies Press, Washington.

36. These thought processes are already evident in projects across the RCUK portfolio. Much of this research is carried out in partnership with manufacturers, material users and waste management organisations to tackle these challenges.

37. EPSRC is currently funding research at the Universities of Oxford, Liverpool and Salford[17] to develop new advanced alloys for use in nuclear fission and fusion applications. The researchers have considered the range of elements available to them taking into account the properties required, including low activity rates from the alloys used. This decision making process has ruled out some strategically important metals in part due to their low natural abundance.

38. In the area of catalysis, EPSRC funded researchers at the University of Bath[18] are looking at ways of developing catalysts based on group II elements. These would be more environmentally benign and place less demand on the world's strategically important resources.

39. However, it should be acknowledged that in many instances substitution is not a viable option thus the way forward is appropriate life cycle thinking combined with research stimulus to ensure the environmental costs—and in particular the carbon costs—are minimised.

Question 5. *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

40. EPSRC and its researchers are engaging with this issue on an international level. One recent example is from a UK-Japan Symposium on Green Manufacturing and Eco-innovation[19] in June 2010, which discussed the future growth area of "urban mining"[20]—how we can treat manufacturing products accumulated as waste as a key resource for the future. EPSRC is also supporting an expert visit to Japan in January 2011 on "sustainable manufacturing" led by Professor Mike Gregory of the Institute for Manufacturing, University of Cambridge.

41. NERC are proposing leading a major research programme on Resource Recovery from Waste (see paragraph 30).

42. The Research Councils put forward key members of the academic community to participate in international committees with a focus on materials. Professor Neil Alford from Imperial College London sits on the European Materials Advisory Panel (MatSEEC). This is an independent science-based expert committee which provides a forum to discuss challenges at an international level and develops Forward Look reports and roadmaps for the different fields of materials science. MatSEEC could be an important future route for international engagement on issues around strategically important metals.

43. A new EC Communication on raw materials will be published in late January 2011. It is anticipated that this will lead to significant research opportunities in this field as part of FP7/ FP8.

Annex 1

STRATEGICALLY IMPORTANT METALS AND THEIR DRIVING EMERGING TECHNOLOGIES

Raw material	*Emerging technologies*
Antimony	Micro capacitors
Cobalt	Lithium-ion batteries, synthetic fuels
Gallium	Thin layer photovoltaics, Integrated Circuits, White LED
Germanium	Fibre optic cable, Infrared optical technologies
Indium	Displays, thin layer photovoltaics
Niobium	Micro capacitors, ferroalloys
Platinum	Fuel cells, catalysts
Tantalum	Micro capacitors, medical technology
Titanium	Seawater desalination, implants

Nb Table adapted from Table 5, page 43 of the Critical raw materials for the EU report.[21]

17 http://gow.epsrc.ac.uk/ViewPerson.aspx?PersonId=13417

18 http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/E03117X/1

19 http://www.raeng.org.uk/international/activities/UK_Japan_Symposium_Green_Manufacturing_Eco_innovation.htm

20 http://www.raeng.org.uk/international/activities/pdf/UK_Japan_Symposium_Green_Manufacturing_Eco_innovation/Kohmei_Halada.pdf

21 European Commission (2010) Critical Raw Materials for the EU. Report of the ad-hoc working group on defining critical raw materials. http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

Annex 2

IMPORTS OF CRITICAL METALS INTO THE UK AND THE EU 32 IN 2008[22]

Commodity	*UK imports* *£ thousand*	*Tonnes*	*EU32 total imports* *Tonnes*
Antimony	7,244	2,552	102,171
Beryllium	2,593	39	n/a
Cobalt	145,117	5,533	91,137
Gallium	n/a	n/a	n/a
Germanium	400	1	n/a
Indium	n/a	n/a	n/a
Lithium	3,568	1,002	33,211
Niobium	6,975	154	154
Platinum Group Metals	1,517,602	1,485	15,566
Rare Earths	10,669	2,508	45,428
Rhenium	Included with Niobium		n/a
Tantalum	8,443	161	885
Tungsten	47,815	3,026	21,874

Note: The above table was provided by BGS. BGS is a global leader in the compilation and publication of annual data[22] on production and trade of metals and mineral commodities for UK, EU and the world. It has carried out this function since 1913. It also provides analysis and advice on global minerals issues. This includes publication of commodity profiles on a range of strategically important metals including rare earths[23], platinum[24] and cobalt[25]

Research Councils UK

17 December 2010

Written evidence submitted by the British Standards Institution (BSI) (SIM 15)

As the UK's National Standards Body, BSI welcomes this opportunity to comment on this inquiry.

BSI is the UK's National Standards Body (NSB) and was the world's first. It represents UK economic and social interests across all of the European and international standards organizations and through the development of business information solutions for British organizations of all sizes and sectors. BSI works with manufacturing and service industries, businesses, governments and consumers to facilitate the production of British, European and international standards.

Much of the market knowledge and expertise BSI has resides in its committee structure. BSI has a large number of committees of experts representing a broad range of stakeholders, and this promotes the development of consensus views regarding standardisation where this is deemed important.

1. *Is there a global shortfall in the supply and availability of strategically important metals essential to the production of advanced technology in the UK?*

1.1 BSI has no particular expertise in analysing or establishing the likelihood of any particular materials or resources becoming unavailable. BSI does, however, publish a great deal of standards that help organisations adopting them run their operations in a way that is truly sustainable based on the consideration of all relevant environmental, social and economic factors. A more detailed explanation of the tools that exist is available on the BSI website:

1.1.1 http://shop.bsigroup.com/en/Browse-by-Subject/Sustainability/

1.2 These tools, and the development of new tools, form the basis of BSI standards-making activity in this area, and it is the adoption of these that will contribute to efforts to ensure the UK's future wealth-making activities are not compromised by events unforeseen environmental, social and political occurrences that put the production of advanced technology at risk.

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22 Source: BGS UK Minerals Yearbook 2009, BGS European Mineral Statistics 2003–2008, BGS World Mineral Production 2004–2008 (see http://www.bgs.ac.uk/mineralsuk/statistics/home.html).
23 BGS (2010) Rare Earth Elements Mineral Commodity Profile (see http://www.bgs.ac.uk/downloads/start.cfm?id=1638)
24 BGS (2009) Platinum Group Metals Commodity Profile (see http://www.bgs.ac.uk/downloads/start.cfm?id=1401)
25 BGS (2008) Cobalt Mineral Commodity Profile (see http://www.bgs.ac.uk/downloads/start.cfm?id=1400)

2. *How vulnerable is the UK to a potential decline or restriction in the supply of strategically important metals? What should the Government be doing to safeguard against this and to ensure supplies are produced ethically?*

2.1 Strategically important metals are no different to any other natural resource in that they all need to be used in a sustainable manner. Sustainable development is defined by the British Standard BS 8900:2006 *Guidance for managing sustainable development* as "an enduring, balanced approach to economic activity, environmental responsibility and social progress". This standard guides organizations towards effective management of their impact on society and the environment, along the route to enhanced organizational performance and success.

2.2 For many organisations, such as the mining and manufacturing industries, the consideration of sustainable materials usage is fundamental to ensuring they operate in a genuinely sustainable manner. With this in mind, BSI is developing another standard that applies the concepts developed in BS 8900 to the use of materials. This standard has the title BS 8905 *Framework for the assessment of the sustainable use of materials* and is due to be published in mid-2011. It will provide a framework for the consideration of environmental, social and economic issues in the sustainable uses of materials. The framework can be applied to all parts of the supply chain, including the source of the material, the use of the material throughout the use phase of a product and the treatment of the material at the end of the product's useful life.

2.3 The Standard is intended to support decisions about the sustainable use of any type of material, and the adoption and implementation of both this and BS 8900 should be encouraged by the Government to safeguard against the decline or restriction in the supply of strategically important metals in a way that is deemed ethical.

3. *How desirable, easy and cost-effective is it to recover and recycle metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

3.1 The recovery and recycling of metals from discarded products should only take place when it has been established that incorporating the metals in the products, and recovering and recycling them at the end-of-life stage is the most sustainable option available. Other options may include using other materials, or adopting other end-of-life options.

3.2 To make this judgement requires a coherent full lifecycle approach encompassing all relevant environmental, social and economic factors. This approach will be articulated in BS 8905 and adoption of these principles will enable sustainable practices to be put into place regarding the use of the metals and their subsequent recovery.

3.3 In relation to other end-of-life options, BSI is currently developing a series of standards for designers and design engineers, BS 8887, *Design for manufacture, assembly, disassembly and end-of-life processing*. These standards aim to give designers recommendations on how best to incorporate into their design documentation, guidance on the ultimate reuse, recovery, recycling and disposal of the components and materials used. A number of specific end-of-life processes have already been covered in the BS 8887 series. The series could be expanded to cover the selection and recovery of materials. A list of the BS 8887 standards currently published and/or in development is as follows:

3.4 BS 8887–1, *Design for manufacture, assembly, disassembly and end-of-life processing—Part 1: General concepts, process and requirements;*

3.5 BS 8887–2, *Design for manufacture, assembly, disassembly and end-of-life processing—Part 2: Terms and definitions;*

3.6 BS 8887–220: *Design for manufacture, assembly, disassembly and end-of-life processing—Part 220: The process of remanufacture—specification;*

3.7 BS 8887–240, *Design for manufacture, assembly, disassembly and end-of-life processing—Part 240: Reconditioning.*

4. *Are there substitutes for those metals that are in decline in technological products manufactured in the UK? How can these substitutes be more widely applied?*

4.1 Substitution can only take place when an individual engineer in full possession of the relevant facts relating to the product being developed is able to make a decision based on the both the performance and sustainability of the candidate materials. To be able to do this the engineer will need access to a wide range of complex engineering data relating to performance and sustainability. Such information is currently difficult to access due to the lack of agreement regarding the categories of information that need to be accessed across different geographical regions and materials classes and in different industries. In addition, the electronic file formats these data are stored in are often proprietary and software platform dependent, meaning long term archiving is difficult due to the rapid obsolescence of the platforms themselves. As a result these data are not easily accessed by the engineers making these judgements.

4.2 The global supply chains are very complex, and a lot of valuable information regarding the sustainability and performance of particular materials and resources is lost, because a particular participant in the chain only has knowledge of direct inputs and outputs. There are efforts in place to create repositories for data, such as the EU Life Cycle Database:

4.3 http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm

4.4 This presents industry-derived data on specific materials using an averaging process. Reliance on these data, however, means that is not possible for a participant to gain competitive advantage by being better than average. To do better than average requires the originators of the data to preserve, archive and make it available in a way that is not currently done. There are a great deal of internationally-developed product data standards developed under ISO/TC 184/SC4 *Industrial Data* that could be applied to this problem and would enable users to generate, retain, archive, and make accessible all relevant data in a way that is secure and does not compromise intellectual property. A summary of these standards is as follows:

4.5 ISO 8000, *Data quality.*

4.6 ISO 10303, *Industrial automation systems and integration—Product data representation and exchange, informally known as Standard for the Exchange of Product Model Data (STEP).*

4.7 ISO 13584, *Industrial automation systems and integration—Parts library (PLIB).*

4.8 ISO 15926, *Industrial automation systems and integration—Integration of life-cycle data for process plants including oil and gas production facilities.*

4.9 ISO 18629, *Industrial automation systems and integration—Process specification language (PSL).*

4.10 These standards could be adapted in such a way that overcomes the problems in identifying and accessing important and complex engineering data. As a result, participants would be able to access all suitable relevant information regarding the attributes of a material, and make better choices in relation to its sustainability.

5. *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

5.1 The marketplace for raw materials, and goods and services using materials, is an international one, and many company, organisation and supply chain boundaries transcend national boundaries. Therefore, it is essential that the foundations upon which co-operation and methods are based are international in nature. As mentioned earlier, many of these methods will be transmitted through the medium of published formal standards. The agreed good practice that is contained within BS 8900 and BS 8905 will be of the highest value if it can be translated into internationally agreed standards at the global and/or European level. BSI, as the UK National Standards Body (NSB) has formal links with the International Standards Organisation (ISO) and the European standards making Body, CEN. Therefore, BSI is in the best position to ensure good practice developed in the UK is adopted more broadly and can also promote the UK as a pioneer in the development of solutions regarding the sustainable use of materials.

5.2 In addition, the UK is a leading participant in the development of standards developed by ISO/TC 184/SC4 *Industrial Data,* and is in a position to lead on developments where there is an opportunity to use standards to enable access to high quality and useful data.

BSI Background

1. BSI is the UK's National Standards Body, incorporated by Royal Charter and responsible independently for preparing British Standards and related publications. BSI has 107 years of experience in serving the interest of a wide range of stakeholders including government, business and society.

2. BSI presents the UK view on standards in Europe (to CEN and CENELEC) and internationally (to ISO and IEC). BSI has a globally recognized reputation for independence, integrity and innovation ensuring standards are useful, relevant and authoritative.

3. A BSI (as well as CEN/CENELEC, ISO/IEC) standard is a document defining best practice, established by consensus. Each standard is kept current through a process of maintenance and reviewed whereby it is updated, revised or withdrawn as necessary.

4. Standards are designed to set out clear and unambiguous provisions and objectives. Although standards are voluntary and separate from legal and regulatory systems, they can be used to support or complement legislation.

5. Standards are developed when there is a defined market need through consultation with stakeholders and a rigorous development process. National committee members represent their communities in order to develop

standards and related documents by consensus. They include representatives from a range of bodies, including government, business, consumers, academic institutions, social interests, regulators and trade unions.

British Standards Institution

17 December 2010

Written evidence submitted by The Cobalt Development Institute (SIM 16)

1. *Is there a global shortfall in the supply and availability of strategically important metals essential to the production of advanced technology in the UK?*

CDI Comment

With regard to cobalt only, the industry does not see this as an issue. The global production of cobalt has consistently increased for the past 20-years and more recently several new projects have come on stream or are about to come on stream, for example FreeportMcMorans's Tenke Fungurume project in DRC and Sherritt International's Ambatovy project in Madagascar. The cobalt market is well supplied with refined and raw material for the foreseeable future. In fact a recent report from CRU Strategies suggests that we are likely entering a phase of oversupply of cobalt for the next five years. The USGS estimates that global cobalt reserves are over seven million tonnes and in the longer term there is also the possibility of mining deep sea mineralised nodules where the resource has been calculated to be around one billion tonnes. Nautilus Mining are just embarking upon the first project of this type and so this source of cobalt (and many other minerals) could become reality on the longer term.

2. *How vulnerable is the UK to a potential decline or restriction in the supply of strategically important metals? What should the Government be doing to safeguard against this and to ensure supplies are produced ethically?*

CDI Comment

The UK is an important user of cobalt and it affects a broad range of industries from superalloys (aerospace and land based gas turbines; hard wearing castings in renewable energy applications), catalysts (clean fuel technology and removal of harmful gases such as NOx), digital storage (essential in computer processing), industrial cutting tools (high speed steels and hard metals), driers in paints and pigments, rechargeable batteries (mainly Li-ion systems), high strength permanent magnets and many other applications. Cobalt is very much a technology enabling metal and important in achieving the stated ambitions of the Government's "green" agenda. To safeguard the UK's important global position in cobalt the UK could consider creating a "Minister for Metals" and should facilitate and encourage good political relations with important supplier countries as this would facilitate access to raw materials in third countries and should allow ethical issues to be more robustly addressed. Also it is considered appropriate to ensure that regulatory matters, such as REACH, are applied in a proportional and sustainable way. Such measures would ensure the best chance for the UK to enjoy uninterrupted supply with a sustainable and valuable future.

3. *How desirable, easy and cost-effective is it to recover and recycle metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

CDI Comment

Much is already being done in this respect and liaison with bodies such as EUROMETAUX would most helpful in obtaining an industry perspective as recycling is an important aspect of sustainability. Resource efficiency is key for a sustainable future and the CDI believes it is important to facilitate the production and import of cobalt as well encouraging recycling. Knowledge of the sector and effective supply chain management are key here.

4. *Are there substitutes for those metals that are in decline in technological products manufactured in the UK? How can these substitutes be more widely applied?*

CDI Comment

It is notoriously difficult to substitute cobalt without suffering serious reductions in efficiency and or performance. In the catalyst sector this is particularly apparent as well as for high performance alloys and in other technology enabling processes. If substitution provided enhanced characteristics or better economy then industry would automatically do this. With cobalt it is not appropriate just to talk about substitution as a means to an end as this could cause serious economic damage to the sector and at the same time cause a reduction is efficiency and effectiveness in certain important processes and applications.

5. *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting strategically important metals?*

CDI Comment

The UK should work to promote good governance, capacity-building and transparency in relation to the extractive industries in developing countries and promoting sustainable exploration and extraction within and outside the UK and EU. The CDI believes that closer co-operation with the African region in general—and the DRC in particular—is needed to ensure that access to essential raw materials by UK companies is facilitated and safeguarded. The EU currently has a Raw Materials Initiative underway which is examining this question. The issues relating to raw materials is complicated and the CDI does not believe that substitution should be an automatic response to perceived criticality of raw materials, rather it is recommended to look at methods which improve and safeguard raw material supply for UK industry.

The Cobalt Development Institute

17 December 2010

Written evidence submitted by Gareth P Hatch (SIM 18)

Disclaimer

The views expressed in this paper are solely those of the author and do not necessarily represent or reflect the views of Technology Metals Research, LLC or those of any other individual or entity.

About the Author

Gareth Hatch is a Founding Principal of Technology Metals Research, LLC. He is interested in helping people to understand the challenges associated with the growing demand for rare-earth elements [REEs] and other critical and strategic materials, and how those challenges affect market sectors throughout the entire technology supply chain. He is currently based in the suburbs of Chicago, Illinois, USA.

For several years Gareth was Director of Technology at Dexter Magnetic Technologies, where he focused on the design & application of innovative magnetic materials, devices and systems, in order to solve real engineering problems. He led a stellar team of engineers who helped customers and clients in the aerospace, defence, medical, data storage, oil & gas, renewables and industrial sectors. He holds five US patents on a variety of magnetic devices.

A two-time graduate of the UK's University of Birmingham, Gareth has a B.Eng. (Hons) in Materials Science & Technology and a Ph.D. in Metallurgy & Materials, focused on rare-earth permanent-magnet materials. He is a Fellow of the UK's Institute of Materials, Minerals & Mining, a Fellow of the UK's Institution of Engineering & Technology, a Chartered Engineer and a Senior Member of the IEEE. Gareth is also a Chartered Scientist and a Chartered Physicist through the UK's Institute of Physics.

Gareth is the Founding Editor of Terra Magnetica, an Editor at RareMetalBlog and is Newsletter Editor and Chicago Chapter Chair of the IEEE Magnetics Society. He is Founder of the Magnetism & Electromagnetics Interest Group and the Strategic Materials Network, both at Linkedin.com. Gareth is also an Advisor to Energy Scienomic, a non-profit organization focused on best practices and standardization of global energy production data and information.

RARE-EARTH ELEMENTS: SUPPLY AND DEMAND CHALLENGES FOR UK INDUSTRY

Introduction and Background

1. As recently noted by the House of Commons Science and Technology Select Committee [1], there is growing speculation on the availability of a variety of metals of strategic importance to UK industry. Unfortunately much of this speculation has been driven by frequently inaccurate media coverage of the sector. Nonetheless, there are some distinct challenges that the UK faces when it comes to the procurement of these metals.

2. Rare earths are almost universally viewed as being of strategic importance. Rare-earth elements (REEs) exhibit special electronic, magnetic and optical properties. In common with a number of other strategic metals, REEs are enablers; although generally used in small quantities, components based on REE alloys and compounds can have a profound effect on the ultimate performance of complex engineering systems.

3. The supply and demand challenges associated with REEs have much in common with other strategically important metals. Given the author's experience with the rare-earth supply chain, the present work focuses primarily on REEs, as it seeks to address the five groups of questions raised by the committee. The answers in many cases are likely to be applicable to other strategic metals too.

Rare-Earth Elements: Terms and Definitions

4. The International Union of Pure and Applied Chemistry (IUPAC) defines the rare earths as a collection of 17 elements of the periodic table [2]. The list includes the 15 lanthanoid elements (atomic numbers 57 through to 71), in addition to scandium (Sc) and yttrium (Y). In practice, Sc does not usually occur in the same minerals as the lanthanoids + Y, and thus the rare-earths industry generally omits reference to it. Also, promethium (Pm) does not occur freely in Nature, and thus we are left with the 15 elements shown in Figure 1.

5. The rare-earths industry further differentiates REEs as being either light or heavy rare earths. In general, the first five lanthanoids are referred to as light REEs (LREEs). This leave the remaining lanthanoids + Y as heavy REEs (HREEs) as shown in Figure 1. Note that this subdivision does not quite match the terminology used by many scientists; there is little reason to delve into this discrepancy any further; suffice it to say that it is important to note exactly which elements are being referred to, whenever the terms "light" REEs or "heavy" REEs are being used in any discussion on the subject. HREEs are generally rarer than LREEs, and are thus generally more valuable. Note that within the industry, it is customary to discuss REEs in terms of their oxide equivalents (REOs).

6. REEs are always found together within any given rare-earth deposit, albeit in different proportions from one deposit to another. The minerals containing the REEs have to be extracted and the individual REEs separated from one another. Because they are chemically very similar, this separation process requires intensive chemical processes. Specific processes have to be fine-tuned for each deposit, because of the unique mineral "signature" of each deposit.

Rare-Earth Demand Drivers

7. Before addressing specific concerns relating to the supply of REEs, it is important to review the key drivers for the growing demand for REE alloys and compounds.

8. Certain REEs might be used directly in compound form, while others may be incorporated into engineered components via alloying with other elements. Such components are then used within sub-assemblies, which are in turn used to create engineered devices and systems. In simplistic terms, any engineered system can be seem as the sum total of a set of sub-assemblies, consisting of a set of components. The materials used in those components are the foundational basis for the entire engineered system.

9. Table 1 shows the estimated 2010 global demand for REEs. These usages correspond to the production of components or component-level goods. 60% of demand comes from China, with 20% coming from Japan and Korea. Usage in the UK and all other countries with the exception of the USA totals 8%, a relatively small proportion of the global demand.

10. The key applications are for use in permanent magnets (primarily Nd, dysprosium (Dy), praseodymium (Pr) and samarium (Sm)), catalysts (primarily lanthanum (La) and cerium (Ce)), metal alloys (primarily La for battery packs) and polishing (primarily Ce for glass and silicon wafer polishing).

11. The steady increase in demand for REEs is directly correlated to overall GDP growth globally. There has also been increased demand, particularly in developed countries, for energy-efficient appliances and devices that use rare-earth-based components.

12. Going forward, the demand for next-generation wind turbines and hybrid and plugin electric vehicles are the key growth drivers for the specific REEs required for those applications. Table 2 shows forecasted demand for 2015, with significant predicted increases in demand for REEs for use in permanent magnets and metal alloys in particular. Market share by region is very similar, though the overall tonnage is significantly increased to 185,000 t.

13. In terms of specific demand by UK industry, very little REE raw material is presently used to produce components in the UK. It is in the use of semi-finished and finished goods such as permanent magnets and other components, and the devices and systems created from them, that companies in the UK generally interact with the rare-earths supply chain.

Q1: *Is there a global shortfall in the supply and availability of rare-earth metals?*

14. Until relatively recently, there have been few supply issues for REEs. In the longer term (2–3 years and beyond for LREEs and 4–5 years and beyond for HREE) there should be few problems in sourcing REEs. The issue comes in dealing with certain supply challenges in the interim periods—the next 0–3 years for LREEs and 0–5 years for HREEs.

15. It is widely accepted that at present, over 97% of global rare-earth production originates in China. However, there are numerous rare-earth deposits located outside of China, many of which have active development projects underway. Over a dozen of these projects are at an advanced stage of development (see Table 3). There is thus no shortage of potential projects that will eventually diversify the global supply of REEs. The time to develop such projects can be considerable, however, and there is growing concern about the availability of materials in the short term, and certain specific REEs in particular.

16. In recent years, China has imposed export quotas on rare-earth shipments out of China. Ostensibly these were put in place by the authorities to allow for the shut down of inefficient, polluting mines and to allow for environmental remediation.

17. Up until the second half of 2010, there have been few real challenges associated with the physical supply of rare earths to the rest of the world from China. Figure 2 shows the export quota levels in recent years, along with official demand numbers from the rest of the world (ROW), as well projected actual demand (an estimated 15–30,000 tonnes per annum of REOs are said to be illegally smuggled out of China to the rest of the world in recent years, and so the actual ROW demand metrics in Figure 2 attempt to account for this). It can be seen that up until 2010, the export quotas from China were broadly in line with ROW demand. The dip in 2009 of demand reflects the global recession and its effects on demand for REEs.

18. It should be noted that export quotas are allocated by the Chinese authorities to individual trading companies in China, some of which are foreign-owned. It should also be noted that the quotas to date have been monolithic—there has been no differentiation between specific REEs or REOs within those quotas. Furthermore, the export quotas do NOT apply to semi-finished or finished goods, such as permanent magnets or magnet alloys, produced in China. As present they apply only to the raw material forms of REEs and simple REE-based compounds.

19. In July 2010, the authorities announced a significant reduction in export quotas for the latter half of the year—a maximum of approximately 8,000 t of REOs for export, bringing the total for 2010 to just over 30,000 t. This was a 40% reduction over the prior year and caused considerable consternation in the rare-earth industry.

20. The result of this action were very significant price increases for the export of LREEs (in some cases by 1,000–1,500%). LREEs are historically lower-value materials than HREEs, and because of the quota limits, Chinese traders prefer to sell HREEs if they can, in order to maximise profits. The underlying base price for the LREEs actually remained largely unchanged; the traders imposed significant surcharges on top of those prices, resulting in the overall price increases. If the quota for 2011 is further reduced, then further price increases are likely.

21. One other ongoing challenge of increasing importance is the fact that the ratios of individual REEs required to fulfill global demand for the various applications listed in Tables 1 & 2, generally do not occur in the same ratios naturally in the various rare-earth deposits available for extraction—either in China or elsewhere. This leads to an imbalance in the production of certain REEs compared to others.

22. There is additional pressure on specific REEs, given the demand for them, and in particular for oxides of Nd, and Dy (for permanent magnets), as well as Eu and Tb (for phosphors). Some projections indicate that there demand for these REEs will outstrip supply, by 2015, even if some of the new projects come on-stream soon.

Q2: *How vulnerable is the UK to a potential decline or restriction in the supply of rare earths? What should the government be doing to safeguard against this and to ensure supplies are produced ethically?*

23. There is relatively little industry in the UK that is directly connected to the rare-earth supply chain at the raw-materials level. Most companies are connected further up the chain, so any vulnerabilities are indirect, though they certainly exist, and are of potential concern.

24. One exception is a company called Less Common Metals (LCM), based in Birkenhead. LCM produces rare-earth-based alloys and compounds. Historically, LCM has taken raw materials produced in China and processed them into semi-finished goods. The company is owned by Great Western Minerals Group, a Canada-based company in the process of developing a formerly producing rare-earth mine in South Africa. The plan is for materials mined and extracted from South Africa, to be refined into metals elsewhere, before being processed into alloys at LCM.

25. Despite the indirect nature of UK industry's interaction with the rare-earth supply chain, it is still potentially vulnerable to disruption on a couple of fronts.

26. The first is on the geopolitical front. There was much coverage in the media recently about an alleged embargo that China placed on REE shipments to Japan, supposedly in retaliation for the arrest of a Chinese fishing vessel captain. Despite these assertions in the media, there was actually little evidence to suggest that the supply disruption to Japan was as a result of retaliatory actions on the part of the Chinese authorities. One only has to revisit Figure 2 to see that individual trading companies in China likely started running out of their allocated quotas months ago. Given the demand, and potential profits to be made, illegal smuggling also increased, and only a few such shipments needed to be intercepted for the authorities to decide to clamp down and to do more rigorous inspections of all such goods (leading to delays, and certain shipments being prohibited).

27. Regardless of the reality of what happened between Japan and China, there is obviously concern that China could, for whatever reason, decide to unilaterally restrict rare-earth shipments to the UK and elsewhere. Note again, however, that it is likely that the cast majority of goods containing REEs, arrive into the UK in the form of components and sub-assemblies produced in China—not the raw materials themselves. Still, relying on the magnanimity of a single country for such exports is certainly a key potential issue.

28. The second vulnerability results from the geographic “bottleneck” caused by the fact that the vast majority of LREEs produced in China, are done so in the Bayun Obo region, up in Inner Mongolia. It would require just one moderate earthquake in this region to potentially devastate the entire global supply chain for these materials. A similar catastrophe in the SE of the country would have similar effects on the supply of HREEs.

29. Diversification of global supply therefore, makes sense, business-wise. Given the relatively small amount of raw material REE goods used by UK industry, however, it is difficult to see how the UK Government might mitigate against either of the above circumstances. The maintenance of a modest stockpile of raw materials, either unilaterally or in conjunction with European partners, might be one way to solve the issue, particularly to help safeguard the capabilities of companies such as LCM and others.

30. In the long term, the UK government might try to encourage the return of companies and manufacturing entities to the UK, who can produce the components and sub-assemblies that contain REE alloys, in order to safeguard supplies of those parts of the supply chain. it might also consider, either unilaterally or together with European partners, following in the footsteps of Japan and JOGMEC, its government-industry partnership-based resource company that goes out around the world to find and to develop natural resources of strategic importance to Japan and its industrial base. Granted, Japan has a much larger user base when it comes to REEs than the UK and Europe, but such an approach is still worth considering.

Q3: *How desirable, easy and cost-effective is it to recover and recycle rare-earth metals from discarded products? How can this be encouraged? Where recycling currently takes place, what arrangements need to be in place to ensure it is done cost-effectively, safely and ethically?*

31. Given the significant resources required to extract and to produce REEs, it is absolutely desirable to try to recover these valuable materials from the waste streams of our society. Historically the over-dispersion of many of these metals into low concentrations made it questionable as to whether such recycling could be done cost-effectively, assuming there was a process available to do it.

32. In the case of REEs, it is likely that the recovery of these materials could be made cost-effective, given the right approach. To date, however, there has been little work done to study the economic feasibility of candidate processes that have been studied academically.

33. Once such process, developed at the University of Birmingham, involves the processing of previously used rare-earth permanent magnets, into a powder form of the underlying magnet alloy, which can then be re-used to make new magnets. The concept does not require the processing of the alloy back into the constituent elements, unlike related processes recently developed in Japan.

34. The perennial challenge for such research teams is the ongoing funding of their research. In the interests of full disclosure the author recently co-founded a private US-based company which has as its sole mission, the funding of feasibility studies for promising recovery technologies for REEs and other rare metals, such as the Birmingham project. The UK Government might consider setting up special initiatives to help fund such feasibility studies, and work towards the goal of developing the logistics infrastructure required to get access to the rare metals in question, perhaps part of other nd-of-life initiatives for consumer and other products.

Q4: *Are there substitutes for rare earths in technological products manufactured in the UK? How can these substitutes be more widely applied?*

35. As described above, REEs are present at the foundational materials level in the “structural hierarchy” of engineering products and systems. It is generally far easier to consider substitutions at the system, sub-assembly or component level, than at this materials level, because of the time that it takes to research new materials systems and microstructures. Because REEs are exploited for their unique optical, electronic and magnetic properties, substitutions are even more difficult in their case.

36. That said, there have been significant efforts made, especially in Japan, to reduce the amount of scarce REEs and other strategic metals in components, while maintaining the original performance characteristics [3]. A good example of this is work being done to reduce the amount of the increasingly scarce HREE Dy in permanent magnets, by manipulating the structure of the magnet alloy at the microscopic level during processing, and “putting” the Dy only in certain places within the alloy where it is actually needed.

37. It is important to note the potential unintended consequences of well-meant substitution efforts, such as reduced systemic efficiencies, or costs of production and so on. It is important not to “throw the baby out with the bath water” in the search for overcoming short-term supply difficulties.

Q5: *What opportunities are there to work internationally on the challenge of recovering, recycling and substituting rare-earth metals?*

38. At present there is relatively little work underway in this area internationally, outside of Japan. The US Department of Energy issued a report in December 2010 calling for the US to get actively involved in such activities [4]; there has been legislation considered in the US Congress designed to encourage such activities, including international cooperation with the European Union and entities within it.

39. It is the author's experience that there is tremendous enthusiasm in both the private and public sectors in numerous countries, particularly in Europe, but also in North America, Japan and Korea, to see such initiatives succeed. Perhaps by combining such activities under a common framework with related activities, momentum could be achieved. There are certainly European Union initiatives underway to encourage collaboration internationally, on the activities suggested by this question.

40. There are precedents for such frameworks, such as the Concerted European Action on Magnetics, initiated in the mid 1980s to incubate fundamental research into rare-earth-based permanent magnets [5]. Perhaps the UK could take the lead in establishing a similar type of framework, involving not just European but also North American, Australian and Asian partners (including institutions in China as well as Japan and South Korea).

Declaration of Interests

41. Except for the recycling-related company mentioned above, the author owns no shares or stock options in any of the companies noted above, Nor in any junior mining or exploration company operating in the rare-earths sector.

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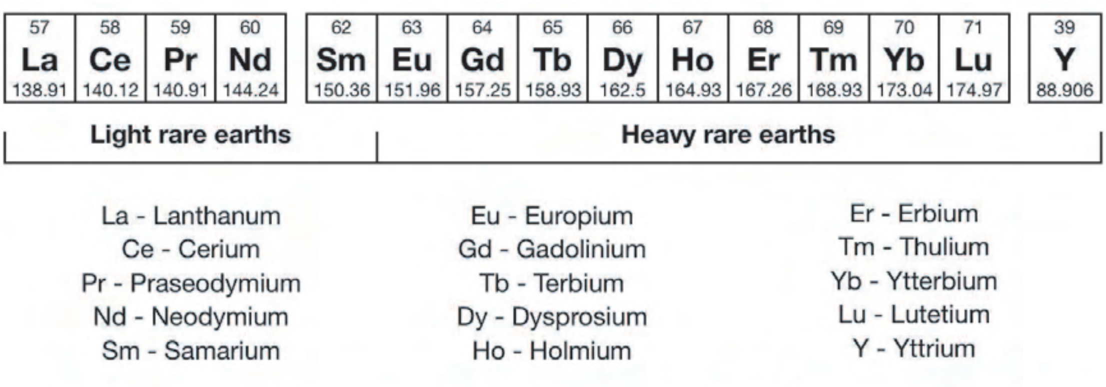
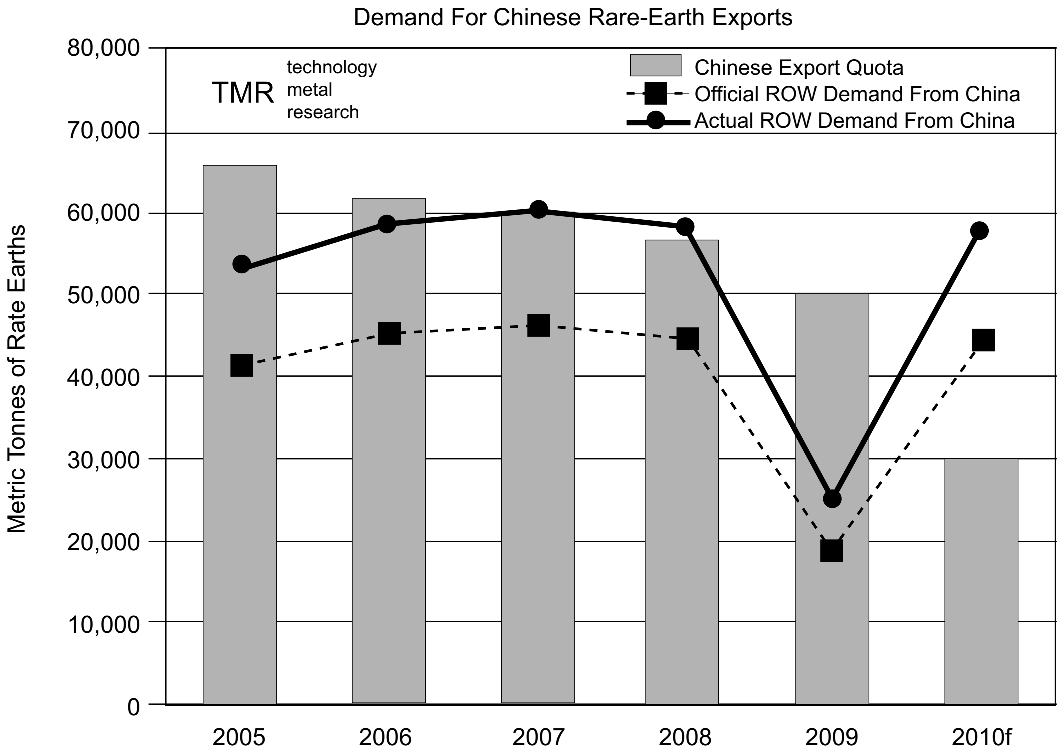


Figure 1: The rare-earth elements - sub-groups per industry (not scientific) norms



Sources: IMCOA, Chinese Ministry of Commerce & Technology Metals Research, LLC

Figure 2: Chinese export quotas and ROW demand for rare-earth exports

Table 1

ESTIMATED GLOBAL RARE-EARTH DEMAND IN 2010 (TONNES OF REO ± 15%)

Application	*China*	*Japan & NE Asia*	*USA*	*Others*	*Total*	*Market Share*
Permanent Magnets	21,000	3,500	500	1,000	**26,000**	**21%**
Catalysts	9,000	3,000	9,000	3,500	**24,500**	**20%**
Metal Alloys	15,500	4,500	1,000	1,000	**22,000**	**18%**
Polishing	10,500	6,000	1,000	1,500	**19,000**	**15%**
Glass	7,000	1,500	1,000	1,500	**11,000**	**9%**
Phosphors	5,500	2,000	500	500	**8,500**	**7%**
Ceramics	2,500	2,500	1,500	500	**7,000**	**6%**
Other	4,000	2,000	500	500	**7,000**	**6%**
Total	**75,000**	**25,000**	**15,000**	**10,000**	**125,000**	**100%**
Market Share	**60%**	**20%**	**12%**	**8%**	**100%**	

(numbers may not add to 100% due to rounding) *Source*: Dudley Kingsnorth / IMCOA

Table 2

ESTIMATED GLOBAL RARE-EARTH DEMAND IN 2015 (TONNES OF REO ± 15%)

Application	*China*	*Japan & NE Asia*	*USA*	*Others*	*Total*	*Market Share*
Permanent Magnets	37,000	6,000	3,000	2,000	**48,000**	**26%**
Catalysts	25,000	7,000	2,000	1,000	**35,000**	**19%**
Metal Alloys	12,500	10,000	4,000	4,000	**30,500**	**16%**
Polishing	12,500	3,000	10,000	3,000	**28,500**	**15%**
Glass	8,000	3,000	1,000	1,000	**13,000**	**7%**
Phosphors	7,000	2,000	1,000	1,000	**11,000**	**6%**
Ceramics	3,000	3,000	2,000	1,500	**9,500**	**5%**
Other	6,000	2,500	500	500	**9,500**	**5%**
Total	**111,000**	**36,500**	**23,500**	**14,000**	**185,000**	**100%**
Market Share	**60%**	**20%**	**13%**	**8%**	**100%**	

(numbers may not add to 100% due to rounding) *Source*: Dudley Kingsnorth / IMCOA

Table 3

CONSTITUENT PROJECTS OF THE TMR ADVANCED RARE-EARTH PROJECTS INDEX (DEC 2010)

Rare-Earth Deposit	*Location*	*Owner*
Bear Lodge	Wyoming, USA	Rare Eelement Resources
Dubbo	New South Wales, Australia	Alkane Resources
Hoidas Lake	Saskatchewan, Canada	Great Western Minerals Group
Kutessay II	Chui, Kyrgyzstan	Stans Energy
Kvanefjeld	Kujalleq, Greenland	Greenland Minerals & Energy
Mount Weld	Western Australia, Australia	Lynas Corporation
Mountain Pass	California, USA	Molycorp
Nechalacho / Thor Lake	Northwest Territories, Canada	Avalon Rare Metals
Nolan's Bore	Northern Territory, Australia	Arafura Resources
Norra Karr	Småland, Sweden	Tasman Metals
Steenkampskraal	Western Cape, South Africa	Great Western Minerals Group
Strange Lake	Quebec, Canada	Quest Rare Minerals
Zandkopsdrift	Northern Cape, South Africa	Frontier Rare Earths
Zeus	Quebec, Canada	Matamec Explorations

Written evidence submitted by the Royal Institution of Chartered Surveyors (RICS) (SIM 22)

The Royal Institution of Chartered Surveyors (RICS) is the leading organisation of its kind in the world for professionals in property, construction, land and related environmental issues. As an independent and chartered organisation, RICS regulates and maintains the professional standards of over 91,000 qualified members (FRICS, MRICS and AssocRICS) and over 50,000 trainee and student members. It regulates and promotes the work of these property professionals throughout 146 countries and is governed by a Royal Charter approved by Parliament which requires it to act in the public interest.

RICS is grateful to the Committee for agreeing to consider its written evidence at this late stage. Given the time constraints, the evidence set out below is brief, but RICS would be happy to expand.

RICS maintains that while Rare Earth Elements are being discarded from obsolete technologies virgin material should not be harvested. RICS supports a comprehensive recycling programme to meet demand and safeguard the future of renewable energy.

Key Points:

- Many of the technologies involved in the green schemes encouraged by Government depend on rare earth metals.
- Rare earth metals may become more difficult to obtain as the country that dominates the market, China, is introducing a policy of restricting production and exports via a system of tariffs and quotas.
- Scarcity of resources is one problem, the association of mining with environmental degradation is another limiting factor.
- Saving the planet through alternative green economies and technologies calls for more access to rare earth metals which in turn could mean more damage to the landscape, more environmental degradation and more loss of wildlife habitats.
- Evidence from the UN suggests that recycling rare earth metals is twice as energy efficient as extracting metals from virgin ores (and in some circumstances ten times more efficient). It may also go some way to keep metal prices down and generate new employment.
- Abundant quantities of rare earth metals exist "above ground" in the form of obsolete consumer technology, with an estimated 30 million computers and laptops containing these metals currently lying unused in the UK.
- RICS maintains that there is an opportunity to harvest rare earth metals present in the Waste Electrical and Electronic Equipment Directive (WEEE). All items under the Directive could be assessed for the presence of these metals and where present should be recovered and returned to the production process. This would require stricter enforcement of the Directive.
- Efficient recovery and re-use of rare earth metals needs to be promoted particularly as the metals are used as a foundation material of most renewable energy technologies.

Royal Institution of Chartered Surveyors

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